AN

INTRODUCTION

TO

NATURAL PHILOSOPHY.

ILLUSTRATED WITH COPPER PLATES.

By WILLIAM NICHOLSON.

Non enim me cuiquam mancipavi, nullius nomen fero: multum magnorum virorum judicio credo, aliquid et meo vindico. Nam illi quoque, non inventa, sed quærenda, nobis reliquerunt. SENECA.

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AN

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TO

NATURAL PHILOSOPHY.

BOOK II.

SECT. III.

Of Fluids.

CHAP. I.

OF HYDROSTATICS, OR THE EFFECTS WHICH ARISE FROM THE GRAVITY OF FLUIDS.

A FLUID is a body whoſe parts readily yield to A
any impreſſion, and in yielding, are eaſily moved
amongſt each other.

The cauſe of fluidity is not perfectly known. B
Some are of opinion that the particles of fluids are
ſpherical, and, in conſequence of their touching
each other in few points, cohere very ſlightly, and
eaſily ſlip or ſlide over each other. But that the
particles of fluids are of the ſame nature or figure

as thofe of folids, feems probable, from the very frequent converfion of the one into the other. It does not feem rational to fuppofe that the particles of gold, lead, glafs, &c. when in fufion, are rendered fpherical by the action of the fire, and when that action ceafes, that the particles refume their former figure, as the bodies become folid by cooling. Neither can we eafily imagine, that the particles of water are changed by cold, when it becomes a folid and brittle lump of ice, and are again reinftated in their original form, when the ice, by diffolution, is again turned to water.

C The original caufe of fluidity, then, does not appear to confift in the figure of the particles, but fimply in their want of cohefion.

D If the particles of a body cohere ftrongly together, it is evident that they will not eafily move amongft each other. An imperfect cohefion muft therefore be one of the properties of a fluid mafs; and that the fmallnefs of the particles is requifite to fluidity, will appear by confidering, that the furface of a body compofed of fmall particles muft be much more fmooth and even than the furface of a body compofed of larger particles: that two *flat bodies may be conceived to confift of particles fo fmall that their furfaces fhall differ infenfibly from perfect planes*: that thefe bodies, if placed on each other, *will flide without the leaft fenfible friction*: and that if the particles of thefe bodies thus placed on each other be, by any means, deprived of the whole, or the greateft part of their cohefion, the bodies

bodies will not only ſlide on each other in the juſt mentioned plane, but the parts of the maſs will alſo ſlide on each other in any other direction whatſoever. Conſequently they will readily yield to any impreſſion, and in yielding, be eaſily moved amongſt each other; that is, they will conſtitute a fluid maſs.

But the enquiry, wherein conſiſts that change E
which bodies undergo when their conſiſtency is altered ſo as to make them aſſume a fluid form, either denſe and almoſt incompreſſible, or vaporous and elaſtic, belongs not to this place, but to chemiſtry.

That ſcience, which treats of the effects ariſing F
from the weight of fluids, is called hydroſtatics.

The parts of fluids are heavy; but becauſe the G
upper parts reſt upon, and are ſuſtained by, the parts beneath, and becauſe, by the property of fluids, the parts are readily moved in all directions, upwards as well as downwards, they do not at firſt conſideration appear to be heavy.

The bottom of an upright priſmical or cylin- H
drical veſſel is preſſed by the whole weight of the fluid contained; and as the weight of the fluid is in proportion to its height, ſo is likewiſe the preſſure. Thus, in the cylinder AB (fig. 114) when filled to C, the bottom is preſſed by, or ſuſtains a certain weight, ſuppoſe one pound; if it be filled to D, the preſſure becomes two pounds; if to A, three pounds, &c. the heights between B, C, D, and A being ſuppoſed equal.

The whole of any fluid maſs may be imagined to I
conſiſt of a number of columns of an inconſiderable

thickneſs, which ſtand perpendicularly on the baſe of the containing veſſel, and preſs the ſame with their reſpective weights. The preſſure, then, if the height remain the ſame, is as the number of columns, and this number is as the area of the

K baſe. Conſequently in veſſels whoſe baſes differ as to area, and which contain fluids of the ſame denſity, but different heights, the preſſure will be in the compound ratio of the baſes and heights; that is, in numbers, as the area of the baſe multiplied by the height of the fluid in one veſſel, is to the area of the baſe multiplied by the height of the fluid in the other veſſel, ſo is the preſſure ſuſtained by the baſe of the one to the preſſure ſuſtained by the baſe of the other veſſel.

L In like ſituations, the preſſures of fluids will be as their denſities.

M The denſities being diſcoverable moſt readily by the different weights of bodies of the ſame bulk, the comparative denſities of bodies are therefore called their ſpecific gravities.

N If the columns of which a fluid maſs was ſuppoſed to conſiſt (3, 1) were formed of particles lying in perpendicular right lines, the preſſure of the fluid would be exerted on the bottom of the veſſel only; but, as they are ſituated in every irregular poſition, there muſt, of conſequence, be a preſſure exerted in every direction; which preſſure muſt be equal at equal depths. For if any part of the whole maſs were not equally preſſed on all ſides, it would move towards the ſide on which

which the preſſure was leaſt; and would not become quieſcent till ſuch equal preſſure was obtained. The quieſcence of the parts of fluids is therefore a proof that they are equally preſſed on all ſides.

On this account it is, that fluids, as far as they O
are not prevented by external accidents, always conform their upper ſurface to the plane of the horizon. For if any column or part of the fluid be elevated above the reſt, it will deſcend partly by ſinking into the fluid, and partly by its lateral preſſure, that will cauſe it to ſpread ſideways over the ſurface, till it becomes uniformly of the ſame height, or horizontal.

The equal preſſure of fluids in every direction, P
being underſtood, may be applied to account for many phenomena that happen to them in different circumſtances; ſome of which are the following.

The horizontal bottom of a veſſel is preſſed by, Q
and ſuſtains no more nor leſs than the weight of a column of the fluid it contains, whoſe baſe is the bottom itſelf, and whoſe height is that of the fluid.

In the veſſel ECDF (fig. 115) the bottom CD R
ſuſtains no more than the column ABDC. For the other parts of the contained fluid can only preſs the column ABDC laterally, and therefore contribute not at all to the increaſe of the weight or preſſure on the bottom CD; but reſt intirely on the ſides EC and FD.

Alſo in the veſſel ECDF (fig. 116), the bottom EF ſuſtains a preſſure equal to the weight of a column whoſe baſe is EF, and height equal to CA.

For the pressure at AB is equal to the weight of the column ABDC, and its lateral pressure, which is equal to the same weight, must cause the parts between EA and BF to press the bottom with an equal force in proportion to the surfaces they cover. Consequently, the effect will be the same as if the whole fluid were of the height CA.

T From these two cases combined, the reason is evident, why fluids contained in the several parts of vessels (fig. 117), remain every where at the same height. For the lowest part where they communicate, may be regarded as the common base; and the fluids, which rest thereon, are in equilibrio then only, when their heights are equal, however their quantities may vary.

U The hydrostatical paradox, as by some it is called, depends on the equal pressure of the parts of fluids every where at the same depth. It is this.

V Any quantity of fluid, however small, may be made to counterpoise and sustain any weight, how large soever.

W Let ADBG (fig. 118) represent a cylindrical vessel, to the inside of which is fitted the cover C, which, by means of leather at the edge, will easily slide up and down in the internal cavity, without permitting any water to pass between it and the surface of the cylinder. In the cover is inserted the small tube CF, open at top, and communicating with the inside of the cylinder beneath the cover at C. The cylinder is filled with water, and the cover put on. Then, if the cover be loaded with

with the weight, ſuppoſe of a pound, it will be depreſſed, the water will riſe in the tube to E, and the weight will be ſuſtained. If another pound be added, the water will riſe through an equal ſpace to F, and the weight will be ſuſtained, and ſo forth, according to the weight added, and the length of the tube. Now, the weight of the water in the tube is but a few grains; yet its lateral preſſure ſerves to ſuſtain as much as the weight of a column of water, whoſe baſe is equal to that of the cylinder, and height equal to that in the tube. Thus, the column E C produces a preſſure in the water contained in the cylinder, equal to what would have been produced by the column A a d D; and, as this preſſure is exerted every way equally, the cover will be preſſed upwards with a force equal to the weight of A a d D: conſequently, if A a d D would weigh a pound, E C will ſuſtain a pound: and the like is true of other heights and weights. And by diminiſhing the diameter of the tube, any quantity of water, how ſmall ſoever, will, in theory, ſuſtain any weight, however large.

The ſame may be ſhewn more ſimply thus:

Let A G B D (fig. 119) repreſent a hollow cylinder, and M N a cylinder of wood, which nearly fills its cavity. In the cylinder, ſuppoſe a little water, whoſe ſurface is g b; then, if the wooden cylinder be put into the hollow one, the water will riſe between the ſurfaces to a and d, and the wood will be ſuſtained floating. The nearer the wooden cylinder approaches to the ſize of the cavity, the leſs water is neceſſary for the experiment.

CHAP. II.

CONCERNING BODIES IMMERSED IN FLUIDS, AND THE METHODS OF FINDING SPECIFIC GRAVITIES.

Y IF a ſolid body be plunged in a fluid, it will be preſſed on all ſides, but not equally. Let DBEC (fig. 120) repreſent a ſolid priſmatic body, immerſed, with its axis vertical, in the fluid contained in the veſſel FGIH, then the ſides DC and BE will be equally preſſed; the upper ſurface DB will be preſſed with the weight of a column, whoſe baſe is DB, and height AD, and the under ſurface will be preſſed upwards with a force equal to the weight of a column whoſe height is AC (4, N). The body will therefore be impelled upwards by a force equal to the exceſs of AC above AD; that is, equivalent to the weight of a column of the fluid whoſe length is DC, the baſe being all along ſuppoſed to
Z be unvaried. Whence it appears, that every priſm, whoſe axis is perpendicular to the horizon, will, if it be totally immerſed in any fluid, be impelled upwards by a force, which is equal to the weight of a quantity of the fluid of the ſame bulk with the priſm. And ſince any ſolid whatſoever may be conceived to be formed of an indefinite number of ſuch priſms, it is evident that the rule is true of all bodies, without reſpect to figure.

But

But as all bodies, by the force of gravity, tend downwards, it depends upon the abſolute weight of the immerſed body, whether it ſhall aſcend or deſcend. If the weight of the body exceed that of an equal bulk of the fluid, the exceſs of force tends downwards, and it will deſcend; but, on the contrary, if the weight of the body be leſs than that of an equal bulk of the fluid, the above-mentioned preſſure will prevail, and it will aſcend; if both be preciſely equal, the body will remain at reſt any where in the fluid. B

These things being conſidered, it appears that any body, how heavy ſoever, may be made to ſwim, or any body, how light ſoever, to ſink, if means be uſed to keep off the preſſure of the fluid from the one or other ſide, as circumſtances require: for if A D B C be ſuppoſed to repreſent an open tube inſtead of a column of the fluid, and the body D B C F be applied cloſely to its lower orifice, ſo that the fluid may not enter the tube, the preſſure on D B will be taken off, and conſequently the body will be preſſed upwards with a force equal to the whole column A C. If that column be of ſufficient length, that is, if the body be immerſed ſufficiently deep, the preſſure will exceed the gravity of the body, and therefore ſuſtain it. In the ſame manner, if M be a body applied to the open end of a tube, which is cloſed at N, the inferior preſſure being taken off, the body will not riſe, however light, but remain immerſed, by means of the preſſure on the ſuperior ſurface. C D E

When

F When a body floats at the surface of a fluid, the quantity of the fluid, displaced by the part immersed, is equal in weight to the floating body. For since the body presses downwards with its whole weight, it must sink till the pressure, which the fluid exerts upwards, is equal to that weight. In this situation, suppose the fluid to be congealed, and the solid then removed: a cavity will be left in the fluid corresponding in form and magnitude with the immersed part of the solid. Imagine this cavity be filled with a quantity of the same fluid, so that its surface may be level with the rest, and the whole fluid then thawed. The fluid which occupies the place of the solid will then be pressed upwards with a force equal to that sustained before by the solid, namely, equal to the weight of the solid. But it is not moved by that force, for the surface must continue level (5, o), as before the thaw. The last mentioned quantity of fluid must therefore press downwards with an equal force. That is to say, the weight of a quantity of fluid equal in bulk to the immersed part of a solid which floats on its surface, is equal to the whole weight of the solid.

G By the same argument, it follows, that if a floating body be loaded with weights, so as to cause it to sink deeper in the fluid, the additional parts immersed will in bulk be equal to, or displace, parts of the fluid, whose weights are equal to those the floating body was loaded with.

Since

Since bodies of equal bulks will lofe the fame quantity of abfolute weight when immerfed in fluids of equal denfity, it follows obvioufly, that the bulks of bodies are in proportion to the lofs of weight they fuftain by immerfion in a given fluid. Whence we have an exact method of determining the bulks of bodies whofe weights are known, and from thence finding their fpecific gravities. For,

As the bulk of one body, or the weight it lofes by immerfion,
Is to its mafs of matter, or abfolute weight,
So is the bulk of any other body, or the weight it lofes by immerfion,
To the mafs of matter, or abfolute weight, it would have had if of the fame fpecific gravity with the firft body. Which weight laft found being compared with the real weight of the latter body, fhews the proportion of their fpecific gravities.

For example: if 34 oz. of lead be weighed in water, and the diminution be 3 oz. and 15 oz. of tin be alfo weighed in water, and the diminution appear 2 oz. it is required to determine the proportion of their fpecific gravities. For which purpofe,

As the diminution in the lead 3, is to its weight 34, fo is the diminution in the tin 2, to the weight of a mafs of lead of the fame bulk $22\frac{2}{3}$ oz. which is to 15 as the fpecific gravity of lead is to that of tin, that is to fay, in lower terms, nearly as $11\frac{1}{3}$ to $7\frac{1}{2}$.

But

L But it is more uſual and convenient to make rain-water the ſtandard, and refer the other ſubſtances to it: thus, in the inſtances juſt mentioned, the weight of a maſs of water equal in bulk to the lead is 3 oz.: lead is therefore to water as 34 to 3, or as $11\frac{1}{3}$ to 1; and in like manner, tin is to water as 15 to 2, or as $7\frac{1}{2}$ to 1.

M When the ſolid is lighter than the fluid in which it is weighed, an additional body of greater denſity may be joined to it: for inſtance, ſuppoſe a piece of cedar-wood, weighing 92 dwts. were required to be weighed; join to it, by means of a ſmall hair or thread, a piece of lead, whoſe weight in water is known, and weigh them immerſed together. The lead will then appear to weigh leſs by 58 dwts. than it did without the addition of the cedar; from whence it is evident that the cedar is impelled upwards by a force that exceeds its own weight by that quantity, or, in other words, that a quantity of water equal in bulk to the cedar, will weigh 92 + 58, or 150 dwts.; conſequently the ſpecific gravities of water and cedar are in proportion as 150 to 92, or in lower terms, as 1 to $\frac{6}{10}$ nearly.

N In this experiment it is neceſſary firſt to ſmear the wood lightly with ſome fat ſubſtance, otherwiſe the water will be imbibed by the wood, and will render it ſpecifically heavier than before. In fact, wood is not ſpecifically lighter than water, but by means of the air-veſſels which run through its ſubſtance.

The

The beſt method to diſcover the ſpecific gravities of fluids is, to weigh the ſame ſubſtance in different fluids; and becauſe the diminution it ſuffers in weight is equal to the weight of a quantity of the fluid of the ſame bulk, we thence obtain the weights of equal quantities of different fluids, and the ſpecific gravities are as thoſe weights; thus, if a piece of glaſs weighed in the concentrated acid called oil of vitriol, loſe 85 grs. and when weighed in water only 40 grs. their ſpecific gravities will be as thoſe numbers, or in lower terms, as $21\frac{1}{4}$ to 10.

The hydrometer, or inſtrument uſually applied to find the ſpecific gravities of liquids, is conſtructed as follows: A B (fig. 121) is a tube of glaſs, joined to a hollow ball C, at the bottom of which is a ſmaller ball D. In the cavity D is placed a quantity of quickſilver, by which the inſtrument is ſo poiſed, that it ſwims in proof ſpirits of wine immerſed to the point M. A quantity of proof ſpirits equal in weight to the whole inſtrument, will therefore be equal in bulk to the immerſed part (10, F). If it be immerſed in another liquid, whoſe ſpecific gravity is greater, it will ſwim with the tube higher out of the water, ſuppoſe to the point B. Then the weights of the quantities diſplaced remaining the ſame, their bulks will be as the immerſed parts of the hydrometer, and the ſpecific gravities of the fluids will be inverſely as thoſe bulks. The proportion which any length of the tube bears to the

the whole bulk of the inſtrument being known, it will not be difficult to graduate the tube ſo as to indicate the ſpecific gravities by inſpection. But this, however, is ſcarcely ever done.

Q This inſtrument is very confined in its uſe. For if the liquors differ conſiderably in ſpecific gravity, they exceed the limits of the graduation: thus the hydrometer, adapted for ſpirits, will ſwim in water with part of the ball above the ſurface; and if it be adapted to water, it will not ſwim in ſpirits at all. It is true, this may be remedied, either by lengthening or widening the tube: but the firſt is inconvenient, and the latter would make the graduations ſo ſhort, as to render them of little uſe.

R To make this inſtrument of more ſervice, there has been added a little plate or diſh D D (fig. 122) at the top of the tube, upon which may be placed weights, as convenience requires. For example, if the whole inſtrument float immerged in ſpirits to the point M, it will require an additional weight to ſink it to the ſame depth in water. Suppoſe the inſtrument to weigh 10 dwts, and to be adjuſted to rectified ſpirits of wine, it will then require the addition $1\frac{6}{10}$ dwt. to ſink it to the ſame point in water. Conſequently it appears, that the ſpecific gravity of water is to that of ſpirits of wine as $11\frac{6}{10}$ to 10, or in lower terms, as 1 to $\frac{86}{100}$.

S This is the beſt hydrometer, both in reſpect to exactneſs and facility in practice. The inſtrument uſed by the officers of Exciſe, is very well adapted

for its purpoſe, which is more confined: it differs from that here deſcribed, by having its additional weights ſcrewed on at a ſtem at E. Theſe inſtruments are uſually of copper.

An attempt has been made * to adapt the hydro- T
meter to the general purpoſe of finding the ſpecific gravity, both of ſolids and fluids (fig. 123.) A is a hollow ball of copper; B is a diſh affixed to the ball by a ſhort ſlender ſtem D; C is another diſh affixed to the oppoſite ſide of the ball by a kind of ſtirrup. In the inſtrument actually made, the ſtem D is of hardened ſteel, $\frac{1}{40}$ of an inch in diameter, and the diſh C is ſo heavy as in all caſes to keep the ſtem vertical, when the inſtrument is made to float in any liquid. The parts are ſo adjuſted that the addition of 1000 grains, in the upper diſh B, will juſt ſink it in diſtilled water, at the temperature of 60° of Fahrenheit's thermometer, ſo that the ſurface ſhall interſect the middle of the ſtem D. Let it now be required to find the ſpecific gravity of any fluid. Immerſe the inſtrument therein, and by placing weights in the diſh B cauſe it to float, ſo that the middle of its ſtem D ſhall be cut by the ſurface of the fluid. Then, as the known weight of the inſtrument added to 1000 grains; is to the ſame known weight added to the weights uſed in producing the laſt equilibrium: ſo is the weight of a quantity of diſtilled water diſplaced by the floating inſtrument; to the weight of an equal bulk of the fluid under

* By the author of this work.

consideration.

consideration. And these weights give the ratio of the specific gravities (4, M). Again, let it be required to find the specific gravity of a solid body less than 1000 grains. Place the instrument in distilled water, and put the body in the dish B. Make the adjustment of sinking the instrument to the middle of the stem, by adding weights in the same dish. Take those weights from 1000 grains, and the remainder will be the weight of the body. Place now the body in the lower dish C, and add more weight in the upper dish B, till the adjustment is again obtained. The weight last added will be the loss the solid sustains (8. Z, A) by immersion, and is the weight of an equal bulk of water. Consequently the specific gravity of the solid compared with water, is as its weight to the loss it sustains by immersion.

U This instrument was found to be sufficiently accurate to give weights true to less than one twentieth of a grain.

V Experiments concerning specific gravities are more difficult to be made with accuracy than authors in general seem to imagine. For we often see tables of specific gravities carried to four, five, and even six places of figures; whereas a difference of a few degrees in the temperature of the water will change the fourth figure. In different specimens of the same wood, the specific gravities will vary in the third figure, as will also metals cast out of the same melting, but cooled more quickly or slowly; and these also are alterable by hammering

ing*. Natural and artificial compounds have likewise great varieties of density in the several specimens denoted by the same name.

A Table of Specific Gravities, extracted from various Authors.

Names	Authors.	Sp. Gravity.
Platina - - -	Kirwan - - -	23.000
Gold - - -	Muschenbroek	19.238 to 19.640
Gold standard of George II.	Muschenbroek -	17.150
Silver - - -	Kirwan, Muschen, -	11.091
Copper - - -	Kirwan -	8.7 to 9.300
Steel soft - - -	Muschenb. -	7.738 to 7.8955
Steel elastic - - -	Muschenbroek -	7.809
Iron bar - - -	Muschenbroek -	7.60 to 7.875
Lead - - -	Muschenbroek	11.226 to 11.479
Tin - - -	Muschenbroek	7.000 to 7.450
Mercury - - -	Muschenbroek	13.55 to 14.110
Zink - - -	Kirwan - -	6.9 to 7.24
Regulus of antimony -	Kirwan - -	6.860
Regulus of arsenic - -	Kirwan - -	8.310
Bismuth - - -	Kirwan - -	9.6 to 9.7
Cobalt, the regulus -	Kirwan - - -	7.7
Nickel - - -	Kirwan -	7.421 to 9.000
Regulus of manganese -	Kirwan - -	6.850
Wolfram, the regulus -†	De Luyart - -	17.6
Common brimstone -	Muschenbroek - - -	1.8
Fine glass - - -	Muschenbroek	3.150 to 3.380
Plate glass - - -	Muschenbroek - -	2.888
Plate glass - - -	B. Martin - -	2.75
Green glass for retorts, &c.	Muschenbroek - -	2.620

* Experiments frequently repeated by the Author have shewn the specific gravity of two nearly equal smooth cylinders of lead, cast out of the same fusion were to each other as 1138 to 1125.

† A chemical analysis of wolfram. London, 1785.

Names.	Authors.	Sp. Gravity.
Crown glafs - -	B. Martin -	2.52
White flint - -	B. Martin -	3.29
White flint - -	- -	3.210
Denfe glafs for achromatic ufes - -	- -	3.437
The concave of an achromatic lens -	- -	3.436
Calcareous fpar (calx aerata) from the fame piece	-	2.711 to 2.726
Ponderous fpar or barytes vitriolata - -	- -	4.474
Quartz - -	Mufchenbroek -	2.763
Rock cryftal - -	Mufchenbroek -	2.650
Diamond - -	Mufchenbroek	3.466 to 3.654
Rain-water - -	- -	1.000
Diftilled water - -	Mufchenbroek -	0.993
River water - -	Mufchenbroek -	1.009
Sea water - -	Mufchenbroek -	1.030
Saturate folution of fea-falt	Mufchenbroek -	1.244
Concentrated vitriolic acid	Bergman -	2.125
Concentrated nitrous acid	Bergman -	1.580
Concentrated muriatic acid	Bergman -	1.150
Concentrated fluor acid -	Bergman -	1.500
Oil of amber - -	Mufchenbroek -	0.978
Oil of fweet almonds -	Mufchenbroek -	0.928
Oil of olives - -	Mufchenbroek -	0.913
Naptha - -	Mufchenbroek -	0.708
Rectified fpirit of wine -	Mufchenbroek -	0.866
Alcohol - -	Mufchenbroek -	0.815
Ether - -	Mufchenbroek -	0.732
Air at the earth's furface	Mufchenb.	0.001 $\frac{2}{3}$ to 0.001 $\frac{1}{4}$
Air. Barometer at 30 In. Thermometer 32° -	Atwood -	0.001279

CHAP.

CHAP. III.

OF THE MOTION OF FLUIDS WHICH ARISES FROM THE PRESSURE OF THEIR SUPERINCUMBENT PARTS.

THE preſſure of fluids being ſhewn to be in proportion to their depths (3, H) it will not be difficult to find the celerities with which they ſpout forth from ſmall apertures in the ſides or bottoms of veſſels.

For this purpoſe let us ſuppoſe P Q S R (fig. 120) to be a priſmical column of any fluid that paſſes through a hole in the bottom of the veſſel F H I G. If the height P Q be aſſumed indefinitely ſmall, the preſſure by which the velocity is produced may be eſteemed conſtant, becauſe the column O P R V, whoſe weight (5, Q) is the meaſure of that preſſure, does not acquire any definite increaſe during the paſſage of the column through its height P Q. The weight of the column O P R V exceeds the weight of the column P Q S R in the ſame proportion as the height P O exceeds the height P Q, and conſequently the action or preſſure exerted on the column P Q S R exceeds its mere gravity in the ſame proportion. Therefore, whatever may be the final velocity, or velocity of emiſſion, produced in the column P Q S R in paſſing through P Q, it will be required, in order to produce an equal final velocity by the mere action of gravity, that the ſame

column ſhould deſcend through a ſpace proportionably greater as this laſt is leſs than the former force (1, 36, H), namely through a ſpace equal to
Y PO. That is to ſay, the velocity of any fluid iſſuing from a hole in the bottom of a veſſel is equal to that which would be acquired by a body falling freely by its gravity through a ſpace equal to the perpendicular height of the fluid above the hole.

Z And becauſe fluids preſs equally every way at equal depths (4, N), this theorem holds good likewiſe with reſpect to fluids that ſpout through apertures at the ſides of veſſels, or with any obliquity whatſoever.

A Hence the motions of ſpouting fluids may be reduced to rule. For every part of the projected ſtream being conſidered as a body in motion, thrown with a given velocity and direction, the ſame principles will be equally applicable to ſpouting
B fluids and to projectiles of any other kind. Thus if the fluid ſpout directly downwards, its velocity in any point of its courſe will be equal to the velocity of emiſſion added to that which it would have acquired by gravity in its fall from the aperture; or, (20, Y) which is the ſame thing, its velocity will be the ſame as if it had fallen from the ſurface of the fluid. If it ſpout directly upwards, it will (1. 31, P. II. 20, Y) proceed with an uniformly retarded motion, which will carry it to the level of the ſurface of the fluid in the veſſel. If it ſpouts in any other direction, its courſe will be nearly a parabola (1. 97, *U*).

On

On theſe conſiderations depends the performance of fountains; for the conſtruction of which there is provided a reſervoir, elevated conſiderably above the plane in which the fountain is to be made. A pipe, communicating with the reſervoir, is conveyed to the middle of a baſon, and by means of a perpendicular ſpout, called the adjutage, throws the water up in the air to a height which is in the level of the ſurface of the water in the reſervoir. C

But in applying theſe obſervations to practice, there are many circumſtances that tend to diminiſh the quantities of motion. There are few fluids that have not a conſiderable degree of coheſion or tenacity, which prevents their parts from moving as freely as otherwiſe they would have done; and the friction againſt the ſides of tubes very much retards the motion of the included fluids, if the tubes be long, ſmall or crooked, and the velocity great. The air which, extricating itſelf from the water, occupies the upper parts of bent pipes, is often a great obſtacle to the courſe of the water, and not unfrequently ſtops its progreſs entirely. In fountains, eſpecially where the fluid is thrown perpendicularly upwards, the part that is falling reſts upon the aſcending column, and prevents its arriving at the height its motion would have carried it to; beſides which, the reſiſtance of the air, and other cauſes, join in increaſing the ſame effect. We muſt not therefore expect in theſe more than in other engines, that the per- D

formance will equal the theory; yet, it is not difficult to make the proper allowances, ſo as to find their real effects by calculation; but our purpoſe, being general, does not extend to the variety of particulars which offer themſelves.

CHAP. IV.

OF THE RESISTANCE WHICH FLUIDS MAKE TO BODIES MOVING IN THEM.

E WHEN a body is immerſed in a maſs or quantity of fluid matter, and is in motion, it muſt ſeparate the parts of the fluid from each other as it moves. If the parts of the fluid be without coheſion or tenacity, this ſeparation will be attended with no difficulty; but if the tenacity be conſiderable, it will require a conſiderable force to overcome it. A part of the motion muſt therefore be loſt in producing this effect. And, in the ſame fluid, the more parts are divided in a given time, the greater quantity of the motion muſt be loſt or employed for that purpoſe. But a body, moving through an uniform fluid, divides a greater or leſs number of its parts, in proportion as the velocity of its motion is greater or leſs.
F Conſequently, the reſiſtance which an uniform fluid makes, by reaſon of its tenacity, to a body immerſed and moving in it, is in proportion to the velocity of the moving body.

But

But there is another reſiſtance of greater conſe- G
quence, which fluids make to bodies immerſed and moving in them, and ariſes from the inertia of their parts. For if a body be moved in a fluid, it muſt give motion to a certain quantity of that fluid, and the reaction of that quantity will deſtroy part of the motion of the body. Now a body moving through an uniform fluid, gives motion to a greater or leſs number of its parts, in proportion to the velocity of its motion, and is therefore reſiſted in the ſimple proportion of the velocity on that account. Again, a body moving through an uniform fluid, communicates a greater or leſs quantity of motion to each of its parts, in proportion to the velocity of its motion, and is therefore reſiſted in the ſimple proportion of the velocity on that account. On both accounts, then, the reſiſtance H
which ariſes from the inertia of the fluid, is in the duplicate proportion of the velocity of the moving body.

When the ſame body is ſpoken of, the reſiſtance I
and retardation follow the ſame ratio; but, in different bodies, they differ in the ſame manner as motion and velocity. Reſiſtance ſignifies the quantity of motion, and retardation the quantity of velocity which is deſtroyed: for example, if a body be projected with a given velocity in a fluid, and loſe half its motion by the reſiſtance in a given time, its retardation will be half its velocity: but if another body of the ſame bulk, but twice the weight or maſs of matter, be projected with a

like velocity in the ſame fluid, it will be equally reſiſted; but, having twice the quantity of motion, will only loſe one-fourth of its velocity in the ſame time. Thus, though the reſiſtances be equal, the retardation in the latter inſtance is only half the quantity of that in the former.

K In fluids that are not glutinous, the reſiſtance ariſing from their tenacity is inconſiderable, eſpecially in ſwift motion; in which caſe, the reſiſtance from the inertia increaſing as the ſquares of the velocities, while that from the tenacity increaſes only as the velocities themſelves, the proportion of the latter to the former becomes ſo ſmall that it may be neglected. It is uſual therefore, to neglect that reſiſtance which ariſes from the tenacity of fluids.

L In like circumſtances, the reſiſtances of fluids are as their denſities. For the quantity of matter to be moved is in that proportion.

M If a cylinder be moved through an uniform fluid in the direction of its axis, it will ſuffer a reſiſtance equal to that of a ſphere, whoſe diameter and velocity of motion in the ſame fluid are equal to thoſe of the cylinder. For proof of which, ſuppoſe the cylinder to be quieſcent in the middle of a priſmical canal or tube, its axis coinciding with that of the tube. Let this tube be filled with the fluid, and conceive the fluid to be moved through it with a given velocity. Then the fluid will paſs between the ſides of the tube and the cylinder, and its motion will be impeded by its being reduced to paſs

through

through a narrower ſpace. If the ſphere be ſubſtituted in the place of the cylinder, the ſpace through which the fluid is reduced to paſs will be preciſely the ſame, and conſequently its motion will be equally impeded. And, becauſe action and reaction are equal, the cylinder and ſphere in theſe circumſtances will be equally acted upon by the fluid. Now, let the fluid be ſuppoſed quieſcent, and the cylinder or ſphere moved with the ſame velocity, and in the contrary direction to that in which the fluid was before moved; and the relative motions of the fluid and immerſed body will be the ſame as before. Conſequently, the cylinder and ſphere, if moved with equal velocities through a priſmical veſſel containing a fluid, will be equally acted upon in the contrary direction to their motions; that is, they will be equally reſiſted. And, ſince this equality of reſiſtance does not at all depend on the magnitude of the priſmical veſſel, the doctrine may be applied to bodies moving in an indefinitely extended fluid, or fluid contained in an indefinitely large priſmical veſſel. It may, therefore, be applied to all bodies in motion which are deeply immerſed in any fluid.

Hence it appears, that in order to maintain the N uniform motion of a body in a fluid, a conſtant acceſſion of force is required to overcome the reſiſtance; but as in general, there is no ſuch acceſſion in the motions which are performed about us, they all decay by degrees, and at length terminate.

It

O It likewiſe appears, that when a body moves in any fluid, and is acted upon by any conſtant force, it can obtain but a certain degree of velocity. For, as the reſiſtance increaſes with the velocity, but in a higher proportion, namely, as the ſquares, (23, H) it is plain that the reſiſtance at a certain period of the acceleration will become equal to the conſtantly acting force; after which the body will proceed uniformly, and the conſtantly acting force will be employed in overcoming the reſiſtance. On this account it is, that bodies that ſink in water, or other fluids, by the force of gravity, ſoon acquire their utmoſt velocity, and afterwards proceed uniformly. And, in like manner, a ſhip, when it firſt gets under way, proceeds with an accelerated velocity, till the reſiſtance of the water becomes in equilibrio with the action of the wind on its ſails, but afterwards proceeds uniformly, the force of the wind being entirely employed in overcoming that reſiſtance.

P In mathematical ſtrictneſs it is not true, that a body in theſe circumſtances ever arrives at uniformity of motion; for the approach of the reſiſtance to an equality with the impelling force is repreſented by a converging ſeries, the number of whoſe terms is infinite, and their ſum in any finite time is leſs than the impelling force: but the latter terms ſoon become too ſmall to be of any phyſical conſequence.

Q What is here ſaid of reſiſtance is to be underſtood of bodies deeply immerſed in fluids, the parts

parts of which are compreſſed together, and non-elaſtic or incapable of condenſation. Friction is likewiſe neglected. Bodies moving at or near the ſurfaces of fluids, more eſpecially if they be obtuſe, cauſe the fluid to riſe into a heap before the body, at the ſame time that it ſubſides at the hinder part. And ſo likewiſe, obtuſe bodies, moving in elaſtic fluids, condenſe that part of the fluid towards which they are moving, while the part from which they recede is rarefied. In theſe caſes the reſiſtances are greater than would be deduced by the principles here treated of*.

* Principia. II. § 8.

B O O K II.

S E C T. IV.

Of the Air or Atmoſphere.

C H A P. I.

OF THE GENERAL PROPERTIES OF THE AIR, THE DIMENSIONS OF THE ATMOSPHERE, AND THE MEASUREMENT OF THE HEIGHTS OF MOUNTAINS BY MEANS OF THE BAROMETER.

R CONTINUAL experience ſhews, that we are immerſed in a fluid which agitates bodies when it is in motion; reſiſts the motions made in it; ſuſtains bodies floating in it; and, in ſhort, differs very little in its general properties from the groſſer fluids, great rarity, elaſticity, and tranſparency, being its diſtinguiſhing characters.

S The whole maſs of this fluid, with its contents, is called the atmoſphere; a term made uſe of when the effects that ariſe from its form, magnitude, denſity, &c. are conſidered; but when the fluid of which the maſs is compoſed is indefinitely ſpoken of,

of, with a view to develope its qualities, and conſider it independent of the bodies immerſed in, or mixed with it, it is called the air, or air..

Air is a fluid, whoſe particles are not in contact, and repel each other with a force that may be diminiſhed, but cannot be deſtroyed by any degree of cold known in the vicinity of the earth. For, if the particles were in contact the fluid could not be compreſſed, and if they did not repel each other, the fluid could not expand when the compreſſing [illegible] is removed. This property of the air may be ſhewn by various methods: one of the ſimpleſt is, to pour a quantity of quickſilver in the tube ABC (fig. 124), cloſed at A, and open at C. Suppoſe the tube to be filled with quickſilver to E, then the air incloſed in the leg AB will prevent its riſing higher than D. Mark F in the ſame horizontal line with D, and (6, T) the column DB will be in equilibrio with FB; conſequently the quickſilver contained between F and D will not at all preſs on the air between A and D. But the column EF acting with its whole weight on the quickſilver between F and D cauſes it to preſs on the air at D, and condenſe it. By increaſing the quantity of quickſilver the condenſation is increaſed, and it is found, that the ſpaces into which the air is condenſed by different weights are inverſely as thoſe weights; or its denſity is as the preſſure it bears. T U V

One of the firſt objects of enquiry that offer themſelves reſpecting the atmoſphere is its extent W

or

or magnitude. Experience aſſures us, that it is extended over the whole ſurface of the earth and ſea; and it is evident, from the ſuſpenſion and motion of the clouds, that its altitude is conſiderable; but the meaſure of this altitude muſt be obtained from its effects. Thus, if the ſpecific gravity of the air be found, and alſo its whole preſſure on bodies, it will be eaſy to diſcover the quantity of the fluid, and its height, if ſuppoſed to be uniformly denſe. Another method of diſcovering the height of the atmoſphere is deduced from optical conſiderations, by obſerving the effect it has on the light of the Sun.

X To find the ſpecific gravity of the air, let A B (fig. 125) repreſent a bottle, whoſe contents are exactly known; for example, ſuppoſe it capable of holding two pounds of rain-water; let a valve, opening outwards, be fitted at A, and the air be exhauſted from within by means of the air-pump, hereafter to be deſcribed; let the veſſel thus exhauſted be weighed in water, or any other denſe fluid, in the veſſel M N, as repreſented in the figure, after which let the air be admitted. An additional weight of about 14½ grains will be required to reſtore the equilibrium: therefore, the air contained in the veſſel A B weighs 14½ grains, the proportion of which to two pounds is 1 to 800, or 1¼ to 1000.

Y In this experiment the veſſel B is immerſed in water, that the fulcrum of the ſcales being leſs loaded, may turn with leſs friction, and conſequently

quently be more ſenſible. It is attended, however, with ſome difficulties; the chief of which conſiſts in the attraction or repulſion exerted at the ſurface of the water, and this is conſiderable enough to induce ſome philoſophers to weigh the bottle without immerſing it.

The ſpecific gravity of air, being thus diſcovered, z its preſſure may be found by the Torricellian experiment, ſo called from its inventor Torricellius. Let A B (fig. 126) repreſent a glaſs tube of the length of 35 inches or upwards, cloſed at the end A, and open at B, fill the ſame with quickſilver, and cloſe the orifice at B with the finger, or otherwiſe: immerſe the end B in the veſſel of quickſilver C D, and remove the finger from the orifice; the quickſilver will then ſubſide to N in the tube at the height of about 30 inches.

This phenomenon is readily explained on the A common principles of hydroſtatics: for which purpoſe it muſt be remembered, that the preſſure a body, immerſed in the veſſel C D, would ſuſtain, is not only that which ariſes from the weight of the quickſilver, but likewiſe from that of a column of the atmoſphere, incumbent on its ſurface; ſo that every column of the quickſilver preſſes with a force that exceeds its own weight. When the tube is inverted into the veſſel of quickſilver, the ſurface of the column it contains being defended from the preſſure of the atmoſphere, by the cloſure at A, can preſs downwards with no more than its own weight; and will, therefore, be in equilibrio with the preſſure

the

the quickſilver in the veſſel exerts againſt its deſcent, then only, when it is ſo much longer, that the additional quickſilver may be equal to the additional weight which a ſimilar column in the veſſel receives from the preſſure of the atmoſphere;
B that is to ſay, the preſſure of the atmoſphere on any given ſurface is equal to the weight of a column of mercury, whoſe baſe is the given ſurface, and height equal to that at which it ſtands in the Torricellian tube; and this preſſure is the weight of a column of air, whoſe baſe is the given ſurface, and height equal to that of the atmoſphere. Or, generally, becauſe the baſes may be ſuppoſed not to vary, the preſſure of the atmoſphere, is as the height of the mercury in the tube.

An inſtrument conſiſting of a Torricellian tube, with a ſcale adapted for meaſuring the heights of the mercury, is called a Barometer.

C It has been ſhewn, that when the air is condenſed, its denſity is in proportion to the weight that compreſſes it (29, U). By means of the Torricellian tube it may be obſerved, that the ſame proportion obtains when it is rarefied by taking off part of the weight of the ſuperincumbent atmoſphere. For, in any elaſtic fluid at reſt, the ſpring muſt equal the compreſſing force (I. 22, R); and if any part of that force be taken away, it muſt expand till the ſpring becomes equal to the remainder; which will happen if the elaſticity of the fluid be weakened by expanſion. And ſince the preſſures of fluids are as their heights (3, H)

the pressure of the mercury in the tube A B (fig. 126) will be equal to that in the tube A B, when the mercury rests at n in the same horizontal line with N. Now; if a bubble or small quantity of air be admitted into the tube A B, it will depress the mercury below the mark N, till its spring, and the weight of the mercury remaining in the tube, be in equilibrio with the pressure of the atmosphere; that is, if the mercury be depressed to M, that part of the weight of the atmosphere which corresponds with the quantity of mercury M B, will be sustained by the weight of the mercury, and the remainder M N will be sustained by the spring of the included air. The included air then, being pressed by a weight less than that of the whole atmosphere, becomes rarefied or expanded. By variously inclining the tube, or by immersing its lower end to greater depths in the bason, the included air may be made to bear more or less of the weight of the atmosphere, as may be gathered by measuring the perpendicular altitude of M above the surface of the quicksilver contained in the vessel C D; and subtracting it from the altitude B N, which corresponds with the weight of the whole atmosphere, and its contraction or dilatation observed: whence it appears, that the density of air, though greatly rarefied, is proportional to the compressing force.

If two columns of uniform fluids, whose specific gravities differ, be equal in weight, and stand on equal bases, their heights will be reciprocally as their specific gravities (4, L, M. 6, T). The specific

gravities of quickſilver and air are reſpectively 14019 and 1¼: therefore,

As the ſpecific gravity of air, - - - -	
Is to the ſpecific of mercury, - - - -	14019
So is the height of the column of mercury, -	30 inches,
To the height of an equal column of air - -	336456, or 5¼ Engliſh miles.

E This would be the height of the atmoſphere, if it were uniformly of the ſame denſity; but as that is not the caſe, on account of the elaſticity which cauſes the upper parts to expand in proportion as the weight of the ſuperincumbent parts becomes leſs, the altitude muſt be much greater.

F The denſity of the air in that part of the atmoſphere in which we live being ſhewn to be as the weight that compreſſes it, it is plain, if the conſtitution of the air in the ſuperior regions be of the ſame kind, that its denſity at any altitude will be as the weight or quantity of the ſuperincumbent air. Suppoſe A m (fig. 127) to be a column of the atmoſphere, and imagine the ſame to be continued at pleaſure beyond m, ſo as to reach its utmoſt limits. Let this column be divided into an indefinitely great number of equal parts, A b, b c, c d, &c. and the quantity of air contained in any one of thoſe parts, or its denſity, will be in proportion to the quantity of air which is ſuperincumbent on that

that part. Now, the difference between the quantities of air incumbent on any two contiguous parts is the quantity contained in the uppermoſt of thoſe parts; that is, for example, the quantity ſuperincumbent on d is leſs than that which is incumbent on c by the difference or part c d: therefore the quantities contained in the equal parts or diviſions are the differences between the incumbent maſſes of air taken in a regular ſucceſſion; and theſe quantities or differences have been ſhewn to be in proportion to the incumbent maſſes. * Now, it is demonſtrable, that if any ſucceſſion or ſeries of magnitudes do increaſe or decreaſe in ſuch a manner, that the differences ſhall be in proportion to the magnitudes themſelves, then thoſe magnitudes, and conſequently their differences, ſhall be in a continued geometrical progreſſion: whence it fol- G
lows, that the denſities or quantities of air contained in the equal diviſions or parts A b, b c, c d, &c. muſt decreaſe in a continued geometrical progreſſion.

On theſe conſiderations is founded the barome- H
trical method of meaſuring the elevations of mountains, or other eminences. The principles made uſe of may be explained as follows:

If a barometer were carried upwards with an I
uniform motion through the column of air A m,

* Let a, b, c, d, &c. be magnitudes, whoſe differences are as the magnitudes themſelves.

That is	$a-b : b :: b-c : c :: c-d : a$, &c.
Then	$a c = b b$, $b d = c c$, &c.
And	$a : b : c : d$, &c.

(fig. 127) its elevation above the surface of the Earth would increase by the continual addition of the equal spaces A b, b c, c d, &c. so as to be successively represented by the natural series of the numbers 1, 2, 3, &c. but the mercury in the tube would continually descend so as to pass through heights that would be proportional to the pressures or densities of the air (52, B, C) at A, b, c, d, &c.
K that is to say, while the elevations above the surface of the earth increase arithmetically the heights of the mercury in the tube will decrease in a continual geometrical series (35, O).

L Now, it is well known, that if a continued geometrical series, beginning with unity, be ranged in order, with an arithmetical series, beginning with 0, or a cypher, the numbers of the latter series will be the logarithms of the correspondent numbers of the other. Such are the numbers before us; for the greatest density of the air, or greatest height of the mercury, may be called unity, and answers to an elevation of 0, or nothing above
M the Earth's surface. The elevations above the Earth's surface will therefore be the logarithms of the heights of the mercury in the barometer.

N If therefore we were provided with a table of logarithms, or an arithmetical series of known unities or measures, adapted to that geometrical series which expresses the gradual descent of the mercury, while it is carried with an uniform motion upwards, the differences of the logarithms of any two given heights of the mercury would in fact

fact be the difference of the elevations above the Earth's furface, or it would be the perpendicular fpace through which the barometer had been carried, in order to produce that defcent of the mercury.

But as there is no fuch table in being, it would become neceffary to compute directly from the properties of the geometrical feries, if there were not a method of applying the common tables of logarithms to this purpofe. It is a property of all logarithms, that if the difference between the logarithms of two numbers be taken in one fet of logarithms, and the difference between the logarithms of the fame two numbers be taken in logarithms of another form, the proportion between thefe two differences will be conftant for all pairs of numbers fo taken*. From hence if the difference of two elevations be experimentally found, and the refpective heights of the mercury obferved at each, it will not be difficult to deduce any other difference of elevation from obfervations of the heights of the mercury at each.

* In the following feries,

0.	3.	6.	9.	12.	15.	logar.
0.	2.	4.	6.	8.	10.	logar.
1.	n.	n^2	n^3	n^4	n^5	numbers.

it is obvious, that the logarithm of any number in one feries has a conftant ratio to the logarithm of the fame number in the other feries. And the differences between the logarithms of two given numbers in the two feries of logarithms will have the fame conftant ratio, as being the logarithms of one and the fame number, namely, the quotient of thofe two numbers.

P An example will render this clear. Suppoſe the height of the mercury in a barometer be 29.565 inches, and the height of the mercury in another barometer, placed at an elevation of 710 feet above the former be 28.770 inches, it is required to find the difference of elevation of two barometers, whoſe mercurial columns ſtand reſpectively at 28.9 inches, and 27.5 inches.

Q If the altitude of the mercurial column, 30 inches, be taken as unity, or the firſt term of the geometrical ſeries, the two firſt altitudes will become fractions $\frac{29.565}{30}$, and $\frac{28.770}{30}$ of that unity, the number 710 being the difference of the logarithms, or correſpondent terms of the arithmetical ſeries of elevation, taken in feet. Take now the difference of the common logarithms of thoſe fractions, or, which is the ſame, the difference of the logarithms of their numerators, thus:

29.565 its logarithm,	- -	1.4707779
28.770 its logarithm,	- -	1.4589399
	Difference,	.0118390

R And this difference .0118380 will bear the ſame proportion to the difference of elevation 710, as the difference of the common logarithms of any other two altitudes of the mercury will be to the difference of elevation between them (37, o): ſo that with reſpect to the thing required,

From the logarithm of 28.9	-	1.4608978
Take the logarithm of 27.5	-	1.4393327
The difference is		.0215651

And as .0118380 : 710 : : .0215651 : 1294 feet.

As

As the two firſt terms are of conſtant uſe in s
theſe computations, it will be advantageous to reduce them to the ſimpleſt expreſſion; thus, as .0118380 : 710 : : 1 : 60000 nearly; ſo that, inſtead of working the proportion with the two firſt terms, it will be ſufficient to multiply the difference of the logarithms by 60000, and the product will give the elevation in feet of one barometer above the other.

But to multiply this difference by 60000 is the T
ſame as to multiply it by 10000, and by 6. The multiplication by 10000 is effected by moving the decimal point four places farther to the right: whence it is ſeen, that the decimal point being removed four places to the right, converts the difference of the logarithms into a number that requires to be multiplied by 6 to reduce it into
feet. The number itſelf is therefore the height in U
fathoms and decimal parts:

Conſequently, the ſhorteſt general rule for V
meaſuring heights by the barometer is, take the difference of the logarithms of the heights of the mercury at both ſtations, and the four firſt figures following the decimal point will be the fathoms, and the reſt a fraction of a fathom, expreſſing the elevation.

It is evident, however, that this rule ſuppoſes W
the ſpecific gravity of the mercury to remain unaltered, becauſe its height could not otherwiſe be a ſettled meaſure of the denſities of the air that ſuſtains it. It is likewiſe implied, that the denſity of

the air is ſubject to no other change than may ariſe from its diminiſhed compreſſion in aſcending towards the upper regions of the air: but neither of theſe poſitions can be admitted in the actual prac-
x tice. For all bodies expand and occupy larger ſpaces when their temperature is increaſed. The mercury in the barometer, when heated, will be ſpecifically lighter, and will conſequently aſcend from that cauſe, even though the preſſure of the air ſhould remain unchanged: and the air, when expanded by the ſame agent, will not diminiſh its preſſure after the uſual ratio in aſcending: or, if the ſame geometrical ſeries be ſuppoſed to be retained, the unity of its logarithms will be greater than before, and the general rule, (39, v) inſtead of giving fathoms, will give a number of ſome larger meaſure. Thus, we ſee, that the rule can be true only with reſpect to air of a given temperature, and that in all other caſes it will require to be corrected.

y By a very valuable ſet of experiments it is found, that the mercury in a barometer changes its altitude by heat, according to the following table:

z If the mercury in the barometer ſtand at 30 inches when the temperature is 32°; its changes will be for every degree,

	between	between	between	between
	0 and 32°	32° and 52°	62 and 72	72 and 92
falls	0.0034 inch.	riſ. 0.0033	riſ. 0.0032	riſ. 0.0031

A In order therefore that we may know the effect of the air's preſſure on the barometer, it is required,

that

that its height should be corrected by the addition or subtraction of these quantities, according to the number of degrees of temperature above or below 32°, and in proportion to its height.

It is also pretty well established from barometrical observations, and from experiments made with B air of various densities, that its expansions by heat are as in the following table. The height of the mercury is taken to be the mean between the heights at the extremities of the column of air, and the column entitled correction shews the expansion or diminution of the column of air in thousandth parts C of the elevation given by the general rule (39, v).

Mean height of BAROMETER 30 inches.

Mean Temperature of the air.		Correction.	Difference for 1 inch barom.
92°	Add to Logarithmic elevation.	156.381	6.0925
82		131.188	5.111
72		105.047	4.0925
62		78.427	3.0555
52		51.335	2.0000
42		25.193	0.9816
32	Subtract	0.	0.
22		24.242	0.4722
12		47.532	019259

The philosopher who undertakes to measure D heights barometrically should be provided with two portable barometers, of the best construction, on which he may read off the height of the mercurial columns to the 500th part of an inch; each barometer

meter muſt be fitted up with an attached thermometer, ſet in the wooden frame in the ſame manner as the barometer-tube is. It is convenient that the ball of each thermometer be nearly of the ſame diameter as the barometer-tube: he ſhould alſo be provided with two other thermometers, detached from the barometers. One barometer with its attached and detached thermometers is to be placed in the ſhade, on the eminence, whoſe height is required, while the other remains in the plain below. Theſe muſt be ſuffered to continue in their places at leaſt a ſufficient time for the detached thermometer to acquire the temperature of the air, that is to ſay, till it ceaſes either to riſe or fall. The obſerver on the eminence muſt then make an obſervation of the height of the mercurial column, and alſo of the temperatures exhibited by the attached and detached thermometers at the ſame time that the obſerver in the plain performs the like with the inſtruments below. It will tend much to diminiſh the errors, if three or more ſets of obſervations be taken at each ſtation after ſhort intervals of time, and the mean of the whole be made uſe of as the true obſervation.

E The nearer theſe directions are adhered to the more accurate will be the reſult; but they will admit of conſiderable deviations in the practice. In caſes where better inſtruments cannot be had, any well-made portable barometer, graduated ſo as to ſhew the true fall of the mercury, may afford obſervations by no means to be deſpiſed. For a

ſmall

ſmall error in the poſition of the zero, or lower point, from which the ſcale of inches begins, provided the point be fixed, will not ſenſibly affect the reſult; and the attached thermometer may be diſpenſed with, if an hour or more be allowed for the mercury in the barometer to acquire the temperature of the ſurrounding air, which is ſhewn by the detached thermometer. A ſingle barometer may ſupply the place of two, if the obſervations can, within any moderate ſpace of time, be made firſt in the plain, then on the mountain, and again repeated on the plain: becauſe it may reaſonably be preſumed, that if the two ſets of obſervations on the plain agree together, the common denſity of the air below has not changed during the operation. The obſervations being made, the height may be deduced according to the following ſummary of the contents of the preceding pages:

Firſt. Reduce the height of the mercury in each barometer to the height it would have ſtood at in the temperature of 32°. This is done by adding to the height, or ſubtracting from it the quantity indicated in the table (40, Z, A) for that purpoſe, according to the number of degrees the attached thermometer ſtands below or above 32°, and the obſerved height in the tube. F

Secondly. Take the difference of the logarithms of the reduced heights of the mercury in each barometer; of this difference, the four firſt figures on the left will be the logarithmic elevation in fathoms, the remaining figures being a decimal. This will be G

be the true elevation, if the mean between the temperatures indicated by the detached thermometer be 32°.

H Thirdly. But if the mean temperature of the column of air, as indicated by the detached thermometers, be above or below 32°; find the mean between the two altitudes of the mercury; extract from the table (41, c) the two numbers in the column of differences that range opposite the two temperatures, between which the mean temperature of the column of air lies; multiply each by the number of inches (and parts, if the elevation be great) which the mean altitude of the mercury differs from 30 inches. Subtract these products from the respective opposite numbers in the column of corrections, if the mean altitude of the mercury be less than 30 inches, but add, if it be greater. Find the difference between these two remainders or sums, and multiply it by the number of degrees by which the mean temperature exceeds the lower of the two adjacent temperatures in the table. Divide this product by 10, and add the quotient to the least of the two remainders or sums, last mentioned. The sum will be the true correction in thousandth parts of the logarithmic elevation. Reduce it into fathoms, by multiplying it into the logarithmic elevation, and dividing by 1000. This quotient being added to the logarithmic elevation, if the mean temperature exceeds 32°, or subtracted, if it fall short of 32°, will give the true elevation or perpendicular distance between the two barometers.

Example.

Example. Suppose the following observations I
to be made, it is required to find the elevation, or vertical distance between the barometers.

Lower station.	Upper station.
Caernarvon quay.	Peak of Snowdon.
Height of Mercury, 29.976 in.	26.289 inches.
Attached thermometer, $62\frac{1}{2}°$	- $46\frac{1}{2}°$
Detached thermometer, 62 -	46

The computation. By the table (40, z) the K
reduction for the lower barometer comes out 0.1, which, subtracted from 29.976, gives 29.876. By the same table, the reduction for $46\frac{1}{2}°$, with a column of 26 inches, comes out .042, which, subtracted from 26.282, leaves 26.240 inches. Now, the logarithms of the reduced altitudes, 29.876, and 26.240, are 1.4753225, and 1.4189638, the difference of which is .0563587, or (43, G) 563.587 fathoms.

The mean temperature between 62° and 46° is L
54°, and consequently the logarithmic result will require corrections by the second table. The mean between the two barometrical heights is 28 inches, or 2 inches below 30. The two numbers in the column of difference opposite the temperatures 52° and 62° are 2.0000, and 3.0555; these, multiplied by the number of inches, or 2, give 4.0000 and 6.111; the number 4.0000, subtracted from its opposite in the column of correction, 51.335, leaves 47.335; and the number 6.111, subtracted from 78.427, leaves 72.316; the difference between these

these remainders 47.335 and 72.316 is 24.981, which, multiplied by 2, the number of degrees by which the mean temperature 54° exceeds 52°, the lower of the two adjacent temperatures in the table, gives 49.962. This product, divided by 10, is 4.9962; which quotient, added to 47.335, the least of the two remainders, makes 52.331, the true correction in thousandth parts of the logarithmic elevation.

M The true correction 52.331, being multiplied by the logarithmic altitude 563, produces 29462.353; this divided by 1000 affords a quotient of 29.462353; which is the true correction in fathoms, to be added to the logarithmic elevation, because the mean temperature exceeds 32°: the sum, namely, 563.587, added to 29.462353, makes 593.049353 fathoms, or 3558.297118 feet, for the true elevation required*.

N The intelligent reader will readily perceive, that though the decimals in this computation are mostly retained, yet, it will in general be sufficiently exact, and much less operose, if only the two first decimal figures of any number be retained.

O The advantages of this method, compared with the geometrical method of measuring elevations are,

* This method, which is taken from Col. Roy's excellent paper in the 67th volume of the Philosophical Transactions, may be rendered more easy in the practice, by extending the tables so as to give the corrections at sight, as in some measure done in the original; but the brevity of the present work prevented their being copied here.

first,

first, the instruments are neither very expensive nor even difficult for an ingenious philosopher to make in any country where he can procure quicksilver and glass tubes; but the geometrical method demands instruments of considerable price, which can scarcely at all be constructed by the most ingenious person who is destitute of the tools, and unacquainted with the artifices required to render them correct. Secondly, The barometers require no other adjustment than to observe previously, whether they agree, and to allow for their difference. The barometrical observations are likewise easily made; whereas, on the contrary, the previous adjustment and subsequent use of instruments for measuring angles require a degree of precision and skill not usually obtained without practice. Thirdly, The error of observation in the barometrical method for all elevations is nearly a constant quantity, never amounting to so much as half a fathom for a mistake of the 500th of an inch; but any error either in the measurement of lines or angles proportionally affects the result; so that the greater the elevation required to be measured, the larger the quantity of error. Fourthly, The barometrical observations require no particular circumstances of advantage, either in the figure or situation of the mountains required to be measured, nothing more being required than that both stations be accessible. These observations, and the computation, are performed after the same method in all cases; but in the geometrical method, if the horizontal distance of

of the two ſtations be conſiderable, or if there be not a convenient plain for meaſuring a fundamental baſe, the operation becomes very complicated, and the chance of error is multiplied.

P It muſt not, however, be diſguiſed, that the principles of the geometrical method are eſtabliſhed and ſure, and that an extreme degree of exactneſs may be obtained in this way by good inſtruments in the hands of a ſkilful obſerver. Whereas the modifications of the atmoſphere, with reſpect to the effect which exhalations of various kinds, and the greater or leſs abundance of the electric matter, may have in expanding the air, without changing its temperature, are not yet ſufficiently known to render the corrections altogether as perfect as might be wiſhed. Future obſervations muſt point out theſe, and in the mean time it is to be remembered, that the elevations determined by the barometer, when the extreme temperatures of the column of air do not greatly differ, and when the air is cold and dry, are moſt to be depended on*.

* For a more full account of this curious ſubject, conſult De Luc's Recherches ſur les Modifications de l'Atmoſphere. Sir Geoge Shuckburgh's valuable Obſervations made in Savoy, in order to aſcertain the height of mountains by means of the barometer, inſerted in the Philoſophical Tranſactions, vol. 67. with Col. Roy's, and Mr. de Luc's papers, in the ſame volume: alſo Damen's Diſſertatio Phyſica et Mathematica de Montium Altitudine barometro metienda; and the authors by him cited.

CHAP.

CHAP. II.

OF THE REFRACTIVE POWER OF THE AIR; AND THE CAUSE OF TWILIGHT.

THAT the celeſtial ſpace or heavens is either nearly or abſolutely vacuous, appears from the ſmall reſiſtance the planetary bodies ſuffer in their motions; ſuch reſiſtance, if it obtain at all, being too minute to be clearly aſcertained by any obſervations we are in poſſeſſion of. Light therefore, when incident on our atmoſphere, paſſes from a rarer to a denſer medium, and ought, according to the principles of optics, to be refracted towards the perpendicular (1. 262, A). And this is accordingly the caſe. Let the circle A B C (fig. 130) represent a ſection of the Earth, and the external concentric circle the ſurface of the atmoſphere; let H N be the ſenſible horizon of a place A, and S the Sun beneath the horizon; then a ray of light incident on the ſurface of the atmoſphere at I, will, inſtead of proceeding to a, be refracted towards the perpendicular I E, and that continually the more as the denſity of the medium becomes greater, ſo that it will arrive at A after paſſing through the curve I A; and a ſpectator at A will behold the Sun in the line of the laſt direction of the ray, namely, in that of A s, the tangent to the curve. The apparent elevation which a celeſtial body ſuffers when its rays Q R S

fall with the greateſt obliquity, to wit, when it is ſeen in the horizon, is about thirty-three minutes of a degree: at other altitudes the differences between the true and apparent places are leſs, the incidences and refractions being leſs conſiderable.

T Hence it comes to paſs, that we ſee the celeſtial bodies for ſome time after they are ſet, and before they riſe in reality, by which means we enjoy about three days in the year more day-light than otherwiſe we ſhould: but in the northern parts, where the ſun riſes and ſets more obliquely, and the atmoſphere being condenſed by cold, refracts more ſtrongly, the difference is much greater.

U The refraction, as well as all the other phenomena produced by the atmoſphere, are variable, as the denſity of the air changes. This variation renders the obſervation of low altitudes uncertain, as the allowance for refraction cannot be collected with great preciſion from any tables. The trigonometrical admeaſurement of the heights of lofty mountains is likewiſe rendered leſs accurate from this cauſe.

V A method of diſcovering the height of the atmoſphere is deduced from obſervations of the morning and evening twilight. Notwithſtanding the very great tranſparency of the air, it may be rendered viſible by means of the rays of light reflected from its parts in all directions. This effect is ſeen when the beams of the Sun are admitted into a room through the window-ſhutter, and may frequently be obſerved when the Sun ſhines through the

chaſms

chaſms or openings in a dark cloud: from which cauſe it happens, that thoſe bodies which emit a very ſmall quantity of light are not to be diſcerned in this ſtronger light. In the day-time the ſtars w are inviſible, and the flame of a candle can ſcarcely be ſeen in the ſun-ſhine: were it not for this illumination the ſky would appear black, and the ſhady ſides of objects would be of a dark colour, nearly the ſame as at midnight.

The ſun ſhining on the globe of the earth can x illuminate but one hemiſphere at once, as has already been ſhewn; but it is not ſo with the atmoſphere which environs the globe. Thus, the illuminated part of the globe terminates at D and d, (fig. 128) but the atmoſphere is enlightened as far as B and b. In conſequence of this it happens, that thoſe parts which have already entered into the dark hemiſphere, and to which therefore the Sun is ſet, muſt ſtill enjoy a degree of light that continues as long as any of the enlightened part of the atmoſphere remains in view. This light, which Y gradually decays after ſun-ſet, or increaſes before ſun-riſe, is called the twilight. Let A H C D d b (fig. 129) repreſent a ſection of the Earth in the plane of the Sun's azimuth, and let the ſpace contained between the concentric circles repreſent the atmoſphere: then, the Sun's rays in the directions S B, s b, will illuminate half the globe D C d, and the atmoſphere will be enlightened as far as B and b on each ſide within the dark hemiſphere; which enlightened part, ſo long as it continues above the

horizon of any place, will cauſe a twilight at that place. The ray S D B is a tangent to the Earth at D, and meets the circumference of the atmoſphere at B. From B draw the line B h, a tangent to the Earth at A, which continue towards N; h N will then repreſent the horizon, in which the extreme point B of the enlightened part of the atmoſphere will be ſituated; that is, twilight will be juſt beginning or ending at the place A. The angle S B N, which is equal to the angle A E D, will be the angle of the Sun's depreſſion beneath the horizon H N; and the angle A E B is the half of A E D. Hence, if the depreſſion of the Sun beneath the horizon, and the ſemidiameter of the Earth be known, it will be eaſy to find the height of the atmoſphere. For, in the right angled triangle A B E,

As the ſine complement of half
  the Sun's depreſſion - - A E B 8° 30′
Is to the Earth's ſemidiameter - A E 3437 miles,
So is radius - - ſine 90°
To the hypothenuſe - - - E B 3475 miles.

The difference between which and the ſemidiameter of the Earth, is the line H B, or height of the atmoſphere, 38 geographical, or 44 Engliſh miles. The angle of the Sun's depreſſion is known by the time elapſed between the beginning or end of twilight, and the riſing or ſetting of the Sun; and it is judged to be twilight ſo long as the illumination of the atmoſphere prevents the ſmaller fixed ſtars from appearing. It is alſo obſerved, that the evening are always longer than the morning twilights, which

which muſt ariſe from the rarefaction of the air over the place, after the day's ſun-ſhine. A ſimilar difference is obſerved between the twilights of ſummer and winter.

This explanation is ſufficient to ſhew the cauſe B of the twilight. But in ſtrict computation the refraction to which the light is ſubject three times before it comes to the eye ſhould be allowed for, and will ſomewhat diminiſh the height deduced.

CHAP. III.

CONCERNING THE CAUSES BY WHICH THE SPRING OF THE AIR IS ALTERED, AND WINDS ARE PRODUCED.

THE expanſion of air by heat, while the preſſure C remains the ſame, has already been taken notice of (40, x). Heat therefore increaſes its ſpring, as may be ſhewn by the following experiment:

Let ADB (fig. 131) repreſent a hollow-glaſs- D ball, having a narrow bent tube ACGE affixed to it. The lower part of the bent tube, and part of the ball, is filled with mercury, as in the figure; the ſurface AB within the ball being on the ſame horizontal line with the ſurface at C in the tube. The parts of the mercury will then be in equilibrio, the external ſurface C being preſſed by the weight

of the atmoſphere, and the internal ſurface A B being preſſed by the ſpring of the included air, which is equal to that weight. But if the ball be immerſed in boiling water, the increaſed ſpring of the included air preſſing on the ſurface A B, will raiſe the mercury from C to G, and there ſuſtain it, namely, at the height of 8$\frac{4}{7}$ inches, when the mercury in the Torricellian tube ſtands at 30 inches. And as the contained air is not ſenſibly dilated by the extruſion of ſo ſmall a quantity of mercury, the ſuſtentation may be regarded as the entire effect of its ſpring. The ſpring of the included air at the heat of boiling water is therefore not only equal to the weight of the atmoſphere, but likewiſe to an additional preſſure of more than $\frac{8}{30}$ of that weight.

E By the ſame inſtrument, it is found, that the elaſticity of the air is weakened by immerſion in very cold or freezing mixtures. And concluſions ſimilar to theſe may be made by various methods, which the attentive learner will readily diſcover.

F In the foregoing experiment the air was prevented from expanding, in conſequence of its increaſed ſpring, by the preſſure of the mercury, but if, inſtead of putting mercury into the ball, a ſmall quantity be made to hang in the tube, as at G H, it will by its motion indicate the dilatation or con-

G traction of the included air. By a method ſimilar to this it is found, that from the point 0 in Fahrenheit's thermometer to the heat of boiling water, or 212°, common dry air expands ſo as to occupy an additional ſpace more than before, equal to the frac-

tion

tion .48421 of its former bulk. But the expansions of moist air are much greater *.

It will not be difficult from these experiments to point out the causes of many phenomena that happen in the air. For, if any part of the air be either heated, or charged with vapor, it will expand, and in consequence of that expansion become specifically lighter than before. It must, therefore, by the laws of hydrostatics, ascend, and the circumambient air must press in on all sides to supply its place. Hence the cause of the ascent of smoke in a chimney. The air which passes through the fire, or comes within a certain distance from it, is rarefied, and ascends, giving place to the cold air that presses in: this in its turn becomes rarefied, and the ascending current of air continues as long as the fire is kept up, the wind drawing from all parts towards the chimney.

If the fire were in the open air, the heated air would still ascend in a current, and the cooler air press in on all sides; that is to say, a wind would be generated, which would constantly blow towards the fire. The quantity of air rarefied by any fire we can make is so small, that the wind produced by that means is too inconsiderable to be perceived at any great distance from the fire; but the rarefactions

* Muschenbroek's Cours de Physique may be consulted for an abstract of what has been done respecting the expansion of air by *Amontons*, and others. But the most copious and valuable set of experiments are those of Col. Roy, in the Philosophical Transactions, part 2, for the year 1777.

arising from natural causes are sufficient to produce all the winds that agitate the atmosphere.

K The sensible horizon is not only divided into 360 degrees, like other great circles, but also into 32 equal parts, called points of the compass, which are again subdivided into halves and quarters. The points of the compass have each a separate name. The points of intersection between the meridian and the horizon are termed North and South; and two other points, at the distance of 90° from the North and South, are termed East and West: these four are denominated cardinal points. The intermediate points take their names from the cardinal points between which they are situated, as in the figure, where the initial letters N. S. E. W. (fig. 132) stand for the words North, South, East, West.

L A wind is named from the point of the compass from which it blows.

M The different winds may, with respect to their direction, be reduced into three classes, viz. general, periodical, and variable winds.

N General winds blow always nearly in the same direction. In the open seas, that is, in the Atlantic and Pacific Oceans, under the equator, the wind is found to blow almost constantly from the eastward; this wind prevails on both sides of the equator to the latitude of 28°. To the northward of the equator, the wind is between the North and East, and the more northerly the nearer the northern limit; to the southward of the equator, the wind

wind is between the South and Eaſt, and the more ſoutherly the nearer the ſouthern limit.

Between the parallels of 28° and 40° ſouth lat. O
in that tract which extends from 30° Weſt to 100° Eaſt longitude from the meridian of London, the wind is variable, but by far the greater part between the N. W. and S. W. ſo that the outward bound Eaſt India ſhips generally run down their eaſting on the parallel of 36° ſouth.

Beyond the northern limit of the general wind in P
the Atlantic Ocean, the weſterly winds prevail, but not with any certainty of continuance.

Near the weſtern coaſt of Africa, within the Q
limits of the general wind, the winds are found to be deflected towards the ſhore to ſuch a degree, that they are found to blow from the N. W. and S. W. quarters for the moſt part, inſtead of the N. E. and S. E. as is the caſe farther out at ſea.

The general winds are uſually called trade-winds. R

In the Atlantic Ocean, the S. E. trade-wind ex- S
tends as far as 3° north, and the N. E. trade-wind ceaſes at the 5th degree N. In the intermediate ſpace are found calms, with rain, and irregular uncertain ſqualls, attended with thunder and lightning. But this ſpace is ſhifted farther to the northward or ſouthward, accordingly as the Sun's declination is more northerly or ſoutherly.

Periodical winds are thoſe which blow in a cer- T
tain direction for a time, and at ſtated ſeaſons change and blow for an equal ſpace of time from the oppoſite point of the compaſs. Theſe may be divided

divided into two claſſes, viz. monſoons, or winds that change annually; and land and ſea-breezes, or winds that change diurnally.

While the Sun is to the northward of the equinoctial, that is to ſay, in the months of April, May, June, July, Auguſt, and September, the wind blows from the ſouthward over the whole extent of the Indian Ocean; namely, between the parallels of 28° N. and 28° S. latitude, and between the eaſtern coaſt of Africa and the meridian which paſſes through the weſtern part of Japan. In the ſea between Madagaſcar and New Holland, the S. E. wind prevails as far as the equator, where it is deflected, and blows into the Arabian Gulf and Bay of Bengal from the S. W. Between Madagaſcar and the main land of Africa, a S. S. W. wind obtains, and coincides with the S. W. winds in the Arabian Gulf. To the northward of New Holland, the S. E. wind is predominant, but varies very much among the iſlands; and between the peninſula of Malacca and the Iſland of Japan, a S. S. W. wind prevails. All this is to be underſtood for the aforementioned months.

But in the other months, October, November, December, January, February, and March, a remarkable alteration takes place. In the ſea between Madagaſcar and New Holland, the S. E. wind extends no farther to the northward than about the 10th degree of ſouth latitude, the other 10 degrees being occupied by a wind from the oppoſite point of the compaſs, or N. W. at the ſame time that the winds

winds in all the northern parts of the Indian Ocean ſhift round, and blow directly contrary to the courſe they held in the former ſix months. Theſe winds are called monſoons, or ſhifting trade-winds.

Theſe changes are not ſuddenly made. Some w
days before and after the change, there are calms, variable winds, and dreadful ſtorms, attended with thunder, lightning, and rain.

On the greater part of the coaſts of lands ſituated x
between the tropics, the wind blows towards the ſhore in the day-time, and towards the ſea in the night. Theſe periodical winds are termed the land and ſea breezes, and are much affected, both in their direction and return by the courſes of rivers, tides, &c.

Variable winds are thoſe which are ſubjected to y
no period, either in duration or return, and are too well known to need deſcription.

If the air were uniformly of the ſame denſity at z
the ſame height, and the lighter parts always repoſed upon the heavier, it is evident that, the lateral preſſure being equal in every horizontal direction, it would remain at reſt. But if, on the contrary, any portion or part of the air were heavier than the reſt, it would deſcend, or if lighter, aſcend till the equilibrium was reſtored; ſo that either the diſplaced air would occaſion a wind, diverging from a central ſpace in conſequence of the deſcent or pouring down of the heavier air, or elſe the air ruſhing in, would occaſion a wind converging to a central ſpace to ſupply the lighter aſcending ſtream. It A

is therefore evident, that any agent that alters the density of a part of the air will produce a wind.

The density of air is changed by compression, and by heat. Its elasticity is increased by the addition of moisture, and electricity may have likewise some effect of the same kind. The compression the air suffers in the natural course of events, is nearly uniform, and experiments are wanting to decide, whether the addition of moisture to air at any of the usual temperatures does not augment its density as much as the increased elasticity diminishes it; neither have any methods been yet devised to shew, whether air in different situations with respect to electricity is altered in its dimensions. In considering the causes of winds, the principal agent to be attended to must therefore be heat.

c If the Earth did not revolve on its axis, it is plain that the Sun, being stationary over one particular spot, would rarefy the air at that spot: it would consequently ascend by the pressure of the circumambient, and less rarefied air, till it arrived at a region in which the air was sufficiently rare to suffer it to expand on all sides: and thus there would be produced a converging wind near the surface of the Earth, and a contrary or divergent wind in the upper region of the air. But since the Earth does revolve on its axis, and the Sun therefore is not stationary, it must follow, that the place where the air is most rarefied will be found successively in every point of the parallel over which the

Sun moves in the courſe of a day. And as this place continually moves to the weſtward, the lower air muſt as conſtantly follow it. Hence we have the origin of the general N. E. and S. E. trade-winds, which no doubt would extend over the whole of the ſpace between the tropics, were it not for the different temperatures of the continents and iſlands over which the Sun paſſes. For the ſurface of earth is more heated than that of the ſea, by reaſon that the tranſparency of the water permits many of the rays of light to paſs to its interior parts before they are ſtifled and loſt. The air therefore, contiguous to the land, being more heated than that which reſts upon the ſea, will prevent the regularity of the effect. Thus, near the weſtern coaſts of Africa and America, the winds blow from the weſtward, to ſupply the conſtant rarefaction thoſe heated lands produce.

The general N. E. and S. E. trade-winds, pro- D
ducing in the upper region of the air winds in the contrary directions, ſeem to be the cauſe of the weſterly winds which are obſerved to prevail between the latitudes of 28° and 40°.

In accounting for the monſoons, or periodical E
trade-winds, it is neceſſary to mark the peculiar circumſtances which obtain in the Indian Ocean, and which are not found in the Atlantic or Pacific Oceans. They ſeem to be theſe. That the ocean is bounded to the northward by ſhores, whoſe latitude does not exceed the limits of the general trade-wind, and that the general trade-wind falls on lee-ſhores to the weſtward.

The

The Sun being twice in the year vertical in the equator, and never departing more than $23\frac{1}{2}°$. from thence, causes the air in that climate to be hotter than at any other place on the ocean; and is the occasion of the trade-wind, as has already been shewn. Such a rarefied space must extend across the Indian Ocean, and produce a S. E. wind to the southward, and a N. E. wind to the northward of the equator, over which, in the upper regions of the air, the winds return in the contrary directions. This we accordingly see happens in the months of October, November, December, January, February, and March. But when the Sun declines to the northward, and heats the lands there, the air contiguous to those lands become rarefied, and the lower air has a tendency to move that way. This tendency increases as the Sun advances farther North, so that the whole body of the lower air to the northward of the equator moves towards the northern lands, notwithstanding the equatorial rarefaction, which must be supplied by the upper or returning current. It seems then that the body of the lower air in the northern part of the Indian Ocean is determined as to its course by the greater rarefaction: if the rarefaction at the surface of the land be greater than that at the equator, the wind blows to the North, and the contrary happens when the equatorial rarefaction is greatest. When the northerly trade-wind prevails, it blows out of the Arabian Gulf upon the coasts of Arabia, Aynan and Zanguebar, and is reflected into the straits of Mosambique.

Moſambique. And at the other ſeaſon, the general ſoutherly wind ſeems to be reflected to the weſtward by the ſame cauſe.

Theſe, or ſome ſuch like, are probably the cauſes of the winds that prevail in the Indian ſeas. But the obſervations we are in poſſeſſion of are too few and too inaccurate for the purpoſe of forming a theory. H

On the ſame principles it will not be difficult to account for the land and ſea breezes. For, becauſe the land is heated in the day-time, the wind muſt blow in ſhore to ſupply the place of the aſcending rarefied air: and in the night the land cools, and condenſes the air, occaſioning the land breeze. I

The circumſtances that produce the variable winds are referable to thoſe already noticed, but act ſo differently in particular caſes and ſituations, that it is ſcarcely practicable to reduce them to any rule. K

When ſeveral winds converge ſwiftly to one point, the air aſcends with great rapidity, and acquires a whirling motion, like that of water deſcending in a funnel. And as the centrifugal force in this whirling motion of the water is often ſufficient to counterpoiſe the lateral preſſure, and to prevent its approaching the central part, it frequently happens, that a perforation is ſeen quite through the body of the fluid. In like manner, the centrifugal force of the air may become equal to the preſſure of the atmoſphere, and conſequently leave a void ſpace about the center of the motion. This phenomenon L

is called a whirlwind, and ſometimes produces fatal effects. For, partly by the expanſion of the air included in houſes or other buildings; and partly by the violence of the aſcending current, it happens, that bodies near the center of the whirl are blown up into the vacuum, or carried aloſt with great impetuoſity in a ſpiral motion.

M If one of theſe whirlwinds happen at ſea, the preſſure of the atmoſphere being taken off that part of the ſurface over which the vacuum is formed, the water, on the principle of the Torricellian tube, will riſe to the height of thirty-two or thirty-three feet before it will be in equilibrio with the external preſſure. The aſcending warm air being moſt probably charged with vapours, will ſuffer them to be condenſed as it arrives in a colder region, and thus the courſe of the current will be marked by the denſe and opake vapor, and by the continual aſcent a cloud will be formed above. Theſe are the phenoména of water-ſpouts. At firſt a violent circular motion of the ſea is obſerved for the ſpace ſometimes of twenty feet diameter; the ſea riſes afterwards by degrees into a tapering column of about thirty feet in height, at the ſame time that a cloud appears, from which a dark line or column deſcends. This column is met by another, which aſcends ſomewhat like ſmoke in a chimney, from the lower or ſolid part of the ſpout. After this junction the cloud continually increaſes till the whirl ceaſes, and the appearance terminates.

CHAP.

CHAP. IV.

OF SOUND; AND OF MUSIC.

When obtuſe bodies move in elaſtic fluids, they condenſe that part towards which they move at the ſame time that the part they recede from is rarefied. This condenſation or rarefaction muſt produce an undulatory or vibrating motion in the fluid. Thus, if a body by percuſſion or otherwiſe be put into a tremulous motion, every vibration of the body will excite a wave in the air, which will proceed in all directions ſo as to form a hollow ſphere; and the quicker the vibrations of the body ſucceed each other, the leſs will be the diſtance between each ſucceſſive wave. The ſenſation excited in the mind by means of theſe waves which enter the ear, and produce a like motion in a thin membrane, ſtretched obliquely acroſs the auditory paſſage, is called ſound. But the term is frequently uſed to imply not only the ſenſation excited in the mind, but likewiſe the affection of the air, or of the ſonorous body by which that ſenſation is produced. Thus, we ſay, that a ſound is in the air, or that a body ſounds when ſtruck, though the affection of the air or body is very different from the ſenſation. N O

That bodies move or tremble when they produce ſound, requires no particular proof: it is evident in drums, bells, and other inſtruments, whoſe vibra- P

tions being large and ſtrong, are therefore more perceptible: and it is equally clear, that a ſimilar vibration is excited in the air, becauſe this vibration is communicated through the air to other bodies that are adapted to vibrate in the ſame manner: thus, bells, glaſſes, baſons, and muſical ſtrings, will ſound merely by the action propagated from other ſounding bodies.

Q It is eſtabliſhed as well by mathematical reaſoning from the nature of an elaſtic fluid, whoſe compreſſion is as the weight, as from experiment, that all ſounds whatever arrive at the ear in equal times
R from ſounding bodies equally diſtant. This common velocity is 1142 Engliſh feet in a ſecond of time. The knowledge of the velocity of ſound is of uſe for determining diſtances of ſhips, or other objects: for inſtance, ſuppoſe a ſhip fires a gun, the ſound of which is heard 5 ſeconds after the flaſh is ſeen; then, 1142 multiplied by 5, gives the diſtance 5710 feet, or 1 Engliſh mile and 430 feet.

S When the aerial waves meet with an obſtacle which is hard, and of a regular ſurface, they are reflected; and conſequently, an ear placed in the courſe of theſe reflected waves will perceive a ſound ſimilar to the original ſound, but which will ſeem to proceed from a body ſituated in like poſition and diſtance behind the plane of reflection as the real ſounding body is before it. This reflected ſound is called an echo.

T The waves of ſound being thus reflexible, nearly the ſame in effect as the rays of light, may be deflected

deflected or magnified by much the ſame contrivances as are uſed in optics. From this property of reflection it happens, that ſounds uttered in one focus of an elliptical cavity are heard much magnified in the other focus: inſtances of which are found in ſeveral domes and vaults, particularly the whiſpering gallery at St. Paul's Cathedral in London, where a whiſper uttered at one ſide of the dome is reflected to the other, and may be very diſtinctly heard. On this principle alſo is conſtructed the ſpeaking trumpet, which either is or ought to be a hollow parabolic conoid, having a perforation at the vertex, to which the mouth is to be applied in ſpeaking, or the ear in hearing.

In addition to the advantages we enjoy from the u
perception of ſound, when the ſenſe of ſeeing cannot be employed, and in conveying our thoughts to each other by means of the aſſociations formed between words and ideas, we receive great pleaſure from the combination of ſound known by the name of muſic.

If a body be ſtruck, and the vibrations excited v
be all performed in equal times, the undulations produced in the air will be ſo likewiſe, and a ſimple and uniformly ſimilar ſound will be produced, except as to loudneſs or intenſity; for, as the vibrations grow leſs ſtrong, the ſound decays. But if the vibrations excited be various and diſſimilar, a like variety of diſſimilar undulations will be produced in the air; and the ſound muſt be harſh, as if ſeveral

ſounds were heard together. The firſt of theſe ſounds is a muſical tone, and the latter a noiſe.

w This is confirmed by experience; for we find that thoſe bodies which are the moſt uniform in their texture, and by conſequence beſt adapted to vibrate ſimply and iſochronally, always produce the moſt muſical tones; as for example, maſſes of elaſtic metal, braſs, caſt-iron, and the like. And this tone is more ſtrictly muſical if the metal be ſo formed as to vibrate in the ſimpleſt manner poſſible. Thus, a hollow metallic veſſel or bell, if it be well formed and not damaged in the tuning, will give but one uniform muſical tone, or at leaſt the tones produced will conſiſt of one predominant or principal tone, and ſeveral others that have a perfect muſical agreement with it. A wire of an uniform thickneſs, ſtretched over two hard bridges or fulcrums, will produce the ſame effect. Muſical tones may be obtained by various means; but it will ſufficiently anſwer our preſent purpoſe to attend only to the ſimpleſt method wherein ſtrings or wires are made uſe of.

x Experience and reaſon have eſtabliſhed the following poſitions reſpecting the vibrations of cords or ſtrings.

y The forces or weights which are neceſſary to draw an extended chord A B (fig. 133) out of its place to the diſtances c e, c f, c g, are directly proportional to thoſe diſtances, provided the chord be not too much drawn aſide.

There-

Therefore, ſince the forces with which the chord Z returns to its firſt ſituation, when ſet at liberty, are always in proportion to the ſpace it has to paſs through, the vibrations muſt all be performed in equal times.

If chords differ only in thickneſs, the times of A their vibrations will be directly as their diameters.

If chords differ only in tenſion, the times of B their vibrations will be inverſely as the ſquare roots of the weights by which they are ſtretched.

If chords differ only in length, the times of their C vibrations will be directly as their lengths.

That tone produced by a ſtring that vibrates D quickly is termed acute or ſharp, when compared with the tone of a ſtring that vibrates ſlower; and the tone produced by the latter is called grave or flat, when compared with that of the former.

If two chords be ſtruck, either at the ſame inſtant E or in intermediate ſucceſſion, the coincidence of ſound is pleaſing or diſpleaſing, accordingly as the two tones produced ſtand related to each other in gravity or acuteneſs: if they be ſo related as to afford pleaſure, the coincidence is called a concord, but if not, it is termed a diſcord.

A ſet of tones which follow each other, and afford F pleaſure, is called melody; a ſet of cotemporary tones which afford pleaſure, is called harmony.

The more frequently the vibrations of two chords G coincide with each other the perfecter the concord will be; thus, two equal ſtrings, equally ſtretched, will each give the ſame tone; the vibrations of the one

will coincide with thoſe of the other; and the concord will be moſt perfect: again, two ſtrings, differing only in length; the one being half the length of the other, will vibrate the one twice while the other vibrates once, the coincidence will be at every ſecond vibration of the ſhorter ſtring, and a concord will be produced, but leſs perfect; if the ſtrings be in length as 2 to 3, the coincidence will be leſs frequent, namely, at the third vibration of the ſhorter ſtring, and the concord will be ſtill leſs perfect: and ſo forth.

H By the help of theſe principles all ſtringed inſtruments are conſtructed; that ſeries of muſical tones being ſelected, which experience has ſhewn to be beſt adapted for the purpoſes of melody and
I harmony. The ſeries is called the diatonic ſcale, and its properties, together with the names of the tones, may be ſeen in the following ſcheme:

Names.	Lengths.	Perfection.
Uniſon, or fundamental	1 : 1	Moſt perfect concord.
Second - -	10 : 9	Diſcord.
Third greater	5 : 4	Imperfect concord.
Fourth - - -	4 : 3	Imperfect concord.
Fifth - - -	3 : 2	Perfect concord.
Sixth greater -	5 : 3	Imperfect concord.
Seventh greater	15 : 8	Diſcord.
Octave - -	2 : 1	Perfect concord.

K The above is called the ſharp ſeries, in contradiſtinction to the flat ſeries, or ſcale, wherein the third, ſixth, and ſeventh are leſs or flat, being in the

the ratios of 6 : 5, 8 : 5 and 9 : 5. There are likewiſe other intermediate tones uſed in practice, as the ſecond leſs, and fourth greater, whoſe lengths are as 16 : 15, and 7 : 5. All theſe are found in the conſtruction of inſtruments; that by their means the performer may place his fundamental, or principal note, on any of the tones at pleaſure, and uſe the other tones which ſtand in the above relations to it; ſuch being found ſufficiently near for practice, though not ſo perfectly accurate as in the ſeries the inſtrument is formed for.

The notation of muſic, and the relations of different ſcales to each other, together with the other particulars on which the rules for compoſition and accompanyment depend, require too copious an explanation to be admitted in this place. L

CHAP. V.

A DESCRIPTION OF VARIOUS INSTRUMENTS, CONSISTING CHIEFLY OF SUCH AS DEPEND ON THE PROPERTIES OF THE AIR FOR THEIR EFFECTS.

M THE mercury in the Torricellian tube ſtands at the height of about thirty inches, by means of the preſſure of the air, and in conſidering the phenomena of winds, we have ſeen that this preſſure is not every where alike, nor always the ſame at any particular place. In conſequence of this it happens, that the mercury in the Torricellian tube does not preſerve the ſame invariable altitude: for, when the air at any place is denſe, the mercury ſtands at a greater height than when it becomes lighter (32, B): thus the tube becomes an inſtrument to indicate the varying weight of the atmoſphere, and when fixed in a proper frame with graduations to meaſure the altitude of the mercury, is known by the name of the barometer. The variations are between the altitudes of $27\frac{1}{2}$ and $30\frac{1}{2}$ inches.

N The heights of two barometers cannot be compared together with any exactneſs, unleſs they be both conſtructed in the beſt manner. The ſpecific gravity of the included mercury ought to be accurately found; and it is neceſſary to boil it in the tube, for the purpoſe of effectually excluding the air and moiſture from within. If the ſurface of the

mercury expoſed to the air be larger than that in the tube, and this laſt be leſs than half an inch in diameter, the mercury will not riſe to its full height. This difference ought to be known, and allowed for between different barometers.

The inſtrument, fig. 131, is uſed under the name of the marine barometer, it being uſeful at ſea, where the common barometer is of little ſervice, on account of the ſhip's motion, which cauſes the mercury to librate up and down in the tube. But as this barometer is ſubject to alteration, on account of heat and cold, as well as on account of change in the weight of the air; and the diſtinguiſhing the effects of each is attended with ſome little trouble, it is not much in uſe on ſhore O

There are many contrivances for enlarging the diviſions on the barometer, ſuch as inclining the tube, and the like; but they are all ſubject to inconveniences, on account of friction, which the upright barometer is free from. P

An inſtrument ſimilar to the marine barometer was formerly made uſe of to indicate the varying temperature of the weather. For the marine barometer is alſo a thermometer, and its variations being thus occaſioned by two cauſes, prevent its being applied to either purpoſe. The thermometer, or inſtrument uſed to exhibit degrees of heat and cold, is therefore conſtructed by the uſe of other fluids. Q

The property of expanſion by heat not being peculiar to air, but common to all bodies, we are at R

liberty

liberty to choofe any ſubſtance in nature for a thermometer. In this choice it is required, that the body made uſe of ſhould be ſuch, that its expanſions may be the effect of heat alone, that they may be eaſily and correctly meaſured, and that the body may be capable of performing its office in temperatures very diſtant from each other. As the preſſure of the atmoſphere is not conſiderable enough to alter the dimenſions of denſe bodies in any ſenſible degree, it is plain that their mutations will indicate the effects of heat alone, and conſequently they muſt be very proper for the matter of thermometers: but theſe mutations being very ſmall in proportion to the whole bulk, ſolid bodies muſt be inconvenient for the purpoſe, on account of the great length required to make them perceptible: but in fluids, by means of proper veſſels, it will be eaſy to render the leaſt alteration viſible; for if the neck or ſtem of any glaſs-veſſel be very ſmall in proportion to the contents of the bulb or bottle, the leaſt expanſion of the included liquor
s will occaſion a viſible riſe in the neck. Thus, A B (fig. 134) repreſents a glaſs-tube, whoſe end A is blown into a ball: this ball, and part of the tube, being filled with quickſilver, the leaſt change of the bulk of the quickſilver, and conſequently of the temperature of the circumambient air, or contiguous bodies, is ſhewn by a riſe or fall of the ſurface in the tube; the quantity of which is indicated by the ſcale a b, affixed to the frame of the inſtrument.

Quick-

Quickſilver is the beſt fluid for thermometers, because it is not ſubject either to alter its expanſibility, or to ſoil the tube, and gives beſides a very extenſive ſcale of diviſions. The thermometer uſed in Britain is graduated according to the ſcale of the celebrated Fahrenheit. There are 180 diviſions or degrees between the freezing and boiling water points; the freezing point being reckoned 32° above 0, or the commencement of the ſcale*. The degrees are counted both upwards and downwards from 0. A good thermometer muſt poſſeſs the following properties. The upper end muſt be hermetically ſealed, and the empty ſpace above the quickſilver muſt contain no air, or at moſt very little. This circumſtance is aſcertained by holding the inſtrument with the ball uppermoſt; in which ſituation the mercury will immediately run ſo as to fill the whole capacity of the tube. The ſcale muſt be well adjuſted, and divided according to the capacity of the tube. To prove this, let the thermometer be taken from its ſcale, and laid in ſnow, or pounded ice, juſt beginning to melt: it ſhould be covered nearly as high as the freezing point, or 32° is ſuppoſed to lie. When the mercury becomes ſtationary, mark the tube with the edge of a knife where it ſtands, or, if there be a mark ready made, as there commonly is, obſerve whether it accurately

* Reaumur's ſcale, principally uſed by the French, begins at the freezing point, and proceeds both ways from 0. From freezing to boiling water is 80 degrees.

agrees

agrees with the ſurface of the mercury; if it does, the freezing point is well ſettled. Wrap now ſeveral folds of linen rags or flannel round the tube of the thermometer nearly as high as the ſuppoſed boiling point; hold the ball of the thermometer in the aſcending current of boiling rain-water about two or three inches below the ſurface; pour boiling water on the rags three or four times, waiting a few ſeconds between each time, and wait ſome ſeconds after the laſt time of pouring on water before the boiling point is marked on the tube, in order that the water may recover its full ſtrength of boiling, which is conſiderably checked by pouring on the boiling water. This laſt experiment muſt be made when the barometer ſtands at 29.8 inches. The adjuſtment of the fixed points being thus aſcertained, faſten the thermometer again to its ſcale, and agitate it ſo as to break or divide the thread of mercury in the tube. By variouſly inclining the inſtrument the ſeparated portion of mercury may be made to reſt in different parts of the tube, and its length obſerved on the ſcale. If its length in every part of the tube correſponds to the ſame number of degrees, the ſcale is well divided. This laſt object is by no means to be neglected: for it ſeldom happens that the diameters of thermometer-tubes are ſufficiently regular to admit of a ſcale divided into equal parts. Such a ſcale will uſually produce an error of upwards of a degree near the temperature of 120°, though the

the fixed points be ever ſo well ſettled; and in ſome inſtances the error may even amount to four or five degrees.

Thermometers with ſmall bulbs, and tubes in u
proportion, are the moſt uſeful. For a large volume of mercury requires a conſiderable time to be either heated or cooled, and if it be immerſed in any liquid, it will change the temperature of the liquid much more than a ſmaller inſtrument would have done, and conſequently is leſs adapted to ſhew the temperature of the liquid at the time of its immerſion. If the ſcale of a thermometer be of a dark colour, and the thread of mercury ſmall, its ſtation will be rendered more diſcernible by ſlipping a piece of white paper behind the tube.

The preſſure of the atmoſphere on the outſide of v
a thermometer not being counteracted by the ſpring of any included air, is exerted in diminiſhing the ſize of the bulb, and ſuſtains the mercury ſomewhat higher than it would ſtand, merely by reaſon of its temperature. This is proved by breaking off the ſealed end of the tube; in conſequence of which the mercury immediately falls. This quantity varies with the weight of the atmoſphere, but the quantity of the variation can ſeldom amount to more than the tenth part of a degree. Thermometers with ſpherical bulbs are leſs acted on by the weight of the atmoſphere than others.

If the bent tube C E D (fig. 135) be filled with w
water, and the ſhorter leg E C immerſed in the water contained in the veſſel A B, the water will

all flow out at the aperture D, and the veſſel will be emptied. For the preſſure that ſupports the water in the leg C E is equal to the weight of the atmoſphere, and is counteracted by the weight of the column E C, and the preſſure that ſupports the water in the leg D E is the ſame weight, but counteracted by the column E D. And as E D is longer than E C, the preſſure of the atmoſphere on D will be leſs effectual than that on C; conſequently the whole maſs of water in the tube will move towards the orifice D, receding from the greater preſſure. This inſtrument is called a ſyphon, and is ſometimes uſed to draw liquors out of caſks that are ſo placed as not conveniently to be moved.

x A very probable account of the cauſe of intermitting ſprings may be given on the principle of the ſyphon. For, let G F C (fig. 136) repreſent a cavity or receptacle in the bowels of a mountain, from the bottom of which C, proceeds the irregular cavity or ſyphon C E D: then, if by ſprings or otherwiſe the receptacle begin to fill, the water will at the ſame time riſe in the leg C E of the ſyphon till it has attained the horizontal level H H: when it will begin to flow out by means of the leg E D, and will continue to increaſe in the quantity diſcharged, as the water riſes ſtill higher, till at length the ſyphon will emit a full ſtream, and by that means empty the receptacle. At this period the ſtream will ceaſe, till the receptacle being again filled, will again exhibit the ſame appearance. And theſe periodical returns of flood and ceſſation will

be

be regular, if the filling of the reſervoir be ſo; but the interval of the returns muſt depend on the dimenſions of the apparatus, and the quantity of water furniſhed by the ſprings.

The action of that very uſeful inſtrument the Y
common pump, depends on the preſſure of the atmoſphere. It conſiſts of a pipe C D (fig. 137) whoſe lower end C is immerſed in water: at B is fixed a valve opening upwards, and in the ſuperior part of the tube is worked a piſton A, fitted very cloſely in the pipe by means of leather. In this alſo is a valve opening upwards. Now, if the part above B be filled with water, to render the whole air-tight, the piſton A being thruſt down to B, and afterwards raiſed, will leave a vacuum or void ſpace between B and A, into which the air contained in the lower part of the pipe C B, will expand itſelf. The ſpring of this air being thus weakened by the expanſion, will no longer counterpoiſe the effect of the preſſure of the atmoſphere, and the water will riſe in the tube till the equilibrium is reſtored. By depreſſing the piſton A, the valve B is ſuffered to cloſe, and a part of the air between the valve and piſton eſcapes through A. After a few ſtrokes the whole of the included air is extracted, the water riſes through the valve B, and is diſcharged by the piſton A. This operation may be continued at pleaſure. But if Z
the height B C be more than 34 feet, the water will not riſe to the valve; for a column of freſh water of that length being equal to the weight of the atmoſphere, it can be raiſed no higher by that weight.

weight. Thus it happens for the same reason that the mercury in the barometer never rises beyond a certain height; and if a pump, finished with the utmost exactness on the principle here described, be made to work in mercury, it will not raise it beyond that height.

A The fire-engine acts by means of the weight and elasticity of the air. For it is composed of two barrels, E and D, (fig. 138) in each of which a solid piston or plunger is worked by means of a double lever. These barrels communicate with the water by a pipe, not expressed in the figure: they also communicate with the strong cylinder or vessel C C, by the pipes L and T. At M and K in the barrels are valves opening upwards, and at L and T are valves which open towards the cylinder. In the figure, the piston in D being raised, the water rushes in at K, while that in E being depressed, forces its contents into the cylinder through the valve T. At the next stroke the barrel E raises the water, while the contents of the barrel D are forced into the cylinder: and thus the alternate actions of raising and forcing may be continued at pleasure. Now, the water being forced into the cylinder, compresses the air contained within into a small space; and this air reacting on the water, drives it in a continual stream through the pipe P O Q R, which may be directed as necessity shall require.

B The great force of compressed air is shewn by many experiments, particularly in the performance

of

of the wind-gun. Fig. 139, repreſents a ſection of this inſtrument. A K is the barrel, containing a ball at K. This barrel is contained within another larger tube C D R E, and in the intermediate cavity, the air is compreſſed and kept. M N is a cylindrical cavity in the ſtock or butt end of the piece, in which a piſton works, for the purpoſe of forcing the air into the before-mentioned cavity. The air is prevented from returning by the ſhut or valve P, which is opened by the air, as it is forced in, but at other times, is kept ſhut by the ſpring of the included air. At L is placed another valve, preſſed cloſe by means of a ſpring on the orifice of the barrel, to prevent the air from eſcaping. A wire paſſing through a hole, rendered air-tight by wet and greaſy leather, is affixed to this valve, and appears afterwards at O, in the form of a trigger. When the trigger is drawn back, the valve L opens, and the air ruſhing out, drives the ball with a force that ſeems not much leſs than if it were diſcharged from a muſquet.

A variety of curious and pleaſing fountains may c be formed by the help of the properties of the air combined with hydroſtatical principles. The following is one of the ſimpleſt. A B C D (fig. 140) is a copper veſſel, near two thirds filled with water: at M is ſcrewed in the tube I G, the junction being made air-tight by means of wet and greaſy leather, and in the upper part of the tube is fixed a ſtop-cock H. The ſtop-cock being opened, a forcing ſyringe is ſcrewed on at I, and a great quantity of

air injected, whence the air in the cavity A B F E being very much condensed, presses on the surface of the included water. The stop-cock being then shut, the syringe is removed, and an adjutage screwed on in its place; through which, if the stop-cock be again opened, the water will spout forth with great violence.

D Fig. 141, is a drawing of a very ingenious fountain, whose construction will be better understood from the section exhibited in fig. 142. B C is an open dish, or vessel. R S and T U are reservoirs for water; each of which is divided into two by the partitions V I and X Y. The tube E F passes through without communicating with the upper reservoir, and serves to convey water from the bason B C to the part T X Y of the lower reservoir. The tube G X forms a communication between the part T X Y of the lower, and R V I of the upper reservoir. The tube I K forms a communication between the part R V I of the upper, and Y X U of the lower reservoir. And the tube M L forms a communication between the part Y X U of the lower, and I V S of the upper reservoir. Lastly, there are openings at O N P Q, to fill or evacuate the reservoirs, and an adjutage pipe D I communicating with the part I V S. The mode of action is this: water being poured into the upper reservoir by the openings O and N, the fountain is set upright, the openings being previously closed, and also the adjutage D. The bason B C must then have water poured into it till it ceases to run down the pipe E F. In this state the fountain

fountain may be ſaid to be charged. For the water that has paſſed down E F condenſes the air in the part T X Y, and alſo in the ſuperior part R V I, by means of the tube of communication G H. In the ſame manner the water paſſes from the upper reſervoir down the tube I K into the other lower part Y X U, and condenſes the air there as well as in the other upper part V I S, by means of the pipe of communication M L. The water in the upper part V I S is therefore preſſed by air condenſed by the weight of the column I K, and alſo of the column E F, becauſe I K is in effect preſſed by this laſt. Open the adjutage D, and the water will iſſue out and riſe (20, B) to nearly the height of both the columns E F and I K together. The water in both thoſe columns muſt deſcend, but as the tube E F is ſupplied by the falling jet that iſſues out of the chamber V I S, while the tube I K is ſupplied by the water from the chamber R V I, the fountain will continue to play till the upper chambers V I S and R V I have reſpectively emptied themſelves into the lower chambers T X Y and Y X U.

In many mechanical engines, where the force E
of an elaſtic fluid is required, the ſteam of boiling water is made uſe of, becauſe it is eaſily obtained, is prodigiouſly elaſtic, and may be quickly deprived of its elaſticity.

The firſt engine we have any account of, for F
raiſing water by the force of ſteam, was conſtructed about a century ago upon the principle of the figure, (fig. 143) where H repreſents a copper

boiler placed on a furnace. E is a ſtrong iron veſſel communicating with the boiler by means of a pipe at top, and with the main pipe A B, by means of a pipe I at bottom. A B is the main pipe immerſed in the water at B. D and C are two fixed valves, both opening upwards, one being placed above, and the other below the pipe of communication I. Laſtly, at G is a cock that ſerves occaſionally to wet and cool the veſſel E, by water from the main pipe, and F is a cock in the pipe of communication between the veſſel E and the boiler.

G The engine is ſet to work, by filling the copper in part with water, and alſo the upper part of the main pipe above the valve C, the fire in the furnace being lighted at the ſame time. When the water boils ſtrongly, the cock F is opened, the ſteam ruſhes into the veſſel E, and expels the air from thence through the valve C. The veſſel E thus filled, and violently heated by the ſteam, is ſuddenly cooled by the water which falls on it upon turning the cock G, the cock F being at the ſame time ſhut, to prevent any freſh acceſſion of ſteam from the boiler. In conſequence of this, the ſteam in E becoming condenſed, leaves the cavity within almoſt intirely vacuous: the preſſure of the atmoſphere at B, therefore, forces the water through the valve D till the veſſel E is nearly filled. The condenſing cock G is then ſhut, and the ſteam cock F again opened; the ſteam ruſhing into E, expels the water through the valve C, as it before did

did the air. Thus E becomes again filled with hot ſteam, which is again cooled and condenſed by the water from G, the ſupply of ſteam being cut off by ſhutting F, as in the former operation: the water conſequently ruſhes through D, by the preſſure of the atmoſphere at B, and E is again filled. This water is forced up the main pipe through C, by opening F and ſhutting G, as before. It is eaſy to conceive, that by this alternate opening and ſhutting the cocks, water will be continually raiſed, as long as the boiler continues to ſupply the ſteam.

For the ſake of perſpicuity, the drawing is di- H
veſted of the apparatus that ſerves to turn the two cocks at once, and of the contrivances for filling the copper to the proper quantity. The engines of this conſtruction were uſually made to work with two receivers or ſteam veſſels, one to receive the ſteam, while the other was raiſing water by the condenſation. This inſtrument has been ſince improved, by admitting the end of the condenſing pipe G into the veſſel E, by which means the ſteam is more ſuddenly and effectually condenſed than by water on the outſide of the veſſel.

The advantages of this engine are, that it may I
be erected in almoſt any ſituation, requires but little room, and is ſubject to very little friction in its parts: its diſadvantages are, that great part of the ſteam is condenſed, and loſes its force upon coming into contact with the water in the veſſel E, and that the heat, and elaſticity of the ſteam muſt

be increaſed in proportion to the height the water is required to be raiſed to. On both theſe accounts a large fire is required, and the copper muſt be very ſtrong, when the height is conſiderable, otherwiſe there is danger of its burſting. The following engine is much to be preferred when the work to be done is heavy, and is leſs chargeable in fuel, becauſe it acts by means of ſteam whoſe denſity is not much greater than that of the common air.

K In fig. 144, H repreſents the copper boiler on its furnace. E is a cylindrical veſſel of iron, in which the piſton O O moves up and down; the edges of the piſton being armed with oakum and greaſe, render the whole cavity between the piſton and the bottom of the cylinder air-tight. F is a cock to admit ſteam into the cylinder from the boiler. I K is a lever, attached to the piſton at I, and at K to the piſton of a pump which works on that ſide. P Q is a ſolid piſton moving in the pipe R M, and loaded with a heavy weight at P. A B C is the main pipe that receives the water forced from R M through a valve C opening outwards. N is an air-veſſel communicating with the main pipe. D is a valve opening upwards, and at M is the water to be raiſed.

L In the drawing, the engine is repreſented in the poſition it has at the end of a forcing ſtroke, which is likewiſe its poſition when at reſt. Suppoſe the main pipe A B C to be filled with water, and the water in the copper H to boil ſtrongly.

The

The cock F being then opened, the ſteam ruſhes into the cylinder, and being much lighter than the air, riſes to the top, and expels the air through a valve in the bottom of the cylinder. This being accompliſhed, F is ſhut, and the cock G communicating with the main pipe is opened, which immediately condenſes the ſteam, by violently ſpouting cold water againſt the bottom of the piſton. A vacuum being thus obtained, the preſſure of the atmoſphere forces the piſton down to the bottom of the cylinder; the lever I K is moved of courſe, the piſton P Q with its weight is raiſed, and the water aſcends in the pipe M R upon the principle of the common pump. The cock G being now ſhut, and F opened, the ſteam enters the cylinder, and counteracts the preſſure of the atmoſphere on the piſton O O. In conſequence of this, the weight P prevails, and drives down the piſton R Q, forcing the water through the valve C into the main pipe and its air veſſel. The uſe of the air veſſel is to prevent the main pipe from burſting by the ſudden entrance of the water; for the air at N being elaſtic, gives way to the ſtroke, and its reaction during the time of elevating the piſton P Q continues the motion of the water, ſo that its velocity is no more than half what it would have been if it had been impelled by ſtarts, and reſted during the raiſing of the piſton. By opening the cock G and ſhutting F, the ſteam is again condenſed, the preſſure of the atmoſphere again prevails, and thus the work may be continued at pleaſure.

M In this drawing likewise, the mechanism is omitted, that serves to open and shut the cocks. This office is performed by a beam and ropes attached to the lever I K, so that the attendance required is very little more than is necessary to supply the boiler with water, and to prevent the fire from going out.

N The chief advantage of this engine beyond the former is, that the water may be forced to any height without increasing the force of the steam, which never need be much greater than that of the atmosphere; and therefore the boiler is very little endangered. The maximum of its power depends upon the area of the piston O O; for the larger the area, the greater the column of the atmosphere that presses it, and consequently the heavier the weight P or counterpoise may be. If O O the piston be 36 inches in diameter, it will be pressed by a column of the atmosphere equal in weight to a column of mercury of that diameter, and 30 inches in height; that is to say, almost 7 ton.

O But, notwithstanding the great skill and contrivance displayed in this engine, it is at present almost entirely superseded by one of a much better construction, invented and perfected by Messrs. Watt and Boulton, of Birmingham. In their engine, instead of the piston O O being depressed by means of the weight of the atmosphere, the steam is thrown upon it, the upper part of the cylinder E being closed, and the rod L of the piston which is smooth and polished, being admitted through a perforation,

which

which is wadded so as to be air-tight. The aſcent of the piſton is obtained by letting the ſteam out of the cylinder into a veſſel at a conſiderable diſtance, where it meets with, and is condenſed by a jet of cold water; while a vacuum is conſtantly maintained in the lower part of the cylinder by the action of the pump that carries off the injection water. The force of ſteam employed in this engine is uſually equal to one atmoſphere and a quarter, and the whole apparatus is regularly worked by the principal lever I K. The advantages of this conſtruction are, that by increaſing the force of the ſteam the power of the engine may be increaſed, without enlarging the diameter of the cylinder; and a leſs expence of ſteam is required on account of the condenſation being performed at a diſtance from the cylinder, which is not therefore cooled by the injection of the cold water. This laſt circumſtance renders the engine capable of making a greater number of ſtrokes in a minute with a much leſs expence of fuel than the old engine. In ſome of the lateſt improved engines the action of the ſteam is rendered equal on the lever, by adapting the figure of the arch at its extremity, ſo that the lever is in effect rendered longer, towards the end of the ſtroke, where the power of the ſteam is weaker.

The elaſticity of the air affords a method of determining the depth of the ſea in places where a line cannot be uſed. Fig. 145, is a machine for this purpoſe. A repreſents a large ball of fir P

or

or other light wood, varniſhed over, to preſerve it from the effects of the water; B is a hollow glaſs veſſel, whoſe contents in ſea water are exactly known; ſuppoſe, for inſtance, two pounds: its neck C terminates in a ſmall orifice, and is bent downwards, to prevent the eſcape of the included air, when it is immerſed in water. At E is a ſpring-hook, which, if at liberty, would ſtand in the poſition e, but is preſſed through a ſlit in the ſtem at the bottom, and kept to its place by hooking on the weight D. The whole inſtrument thus prepared is ſuffered to ſink in the water. And the conſequence is, that as it ſinks, the preſſure of the water continually increaſing, forces its way into the veſſel, and condenſes the air contained within; but when it arrives at the bottom, the weight D ſtriking firſt, is ſtopped, while the reſt of the apparatus proceeds a little onwards, by reaſon of its acquired velocity. The hook E being thus diſengaged from the weight, flies back, and leaves it intirely, ſo that the ball A is at liberty to riſe again to the ſurface. From the quantity of water contained in B at its emergence, it is eaſy to determine the depth it has deſcended to. For, ſince the denſity of air is as the compreſſing weight, the bulk of the ſame quantity of air under different preſſures, muſt be inverſely as the weight. And experiment ſhews, that the mean weight of the atmoſphere is equal to about 32 feet of ſea-water: therefore, at the depth of 32 feet, the air included in the veſſel C will ſuſtain the preſſure of

two atmofpheres, and confequently will be condenfed into half its former fpace; at 64 feet depth it will fuftain the preffure of three atmofpheres, and be condenfed into one third of its firft fpace, and fo forth. Suppofe, for example, an empty ball, as above defcribed, capable of holding two pounds troy of fea-water, were to defcend to an unknown depth in the fea, and at its return was found to contain 1lb. 11 oz. 18 dwts. of water, it is required to find the depth? Then, as the bulk the air was compreffed into, when at the bottom of the fea, which is expreffed by 2 dwts. Is to the bulk of the air before immerfion, expreffed by 2 lb. So is the weight of the atmofphere, by which the air was compreffed before immerfion, which is expreffed by 32 feet of water, To the weight by which the air was compreffed when at the bottom of the fea, 3840 feet. From which deduct 32 feet for the preffure of the atmofphere, and the remainder, 3808 feet, indicates the depth of the fea.

This method is fubject to two objections. The first is, that probably the fpecific gravity of the fea may be different at different depths, and confequently the preffures may not be as the depths: the other is, that air in very great condenfations does not ftrictly follow the ratio of the preffure, but refifts in a greater degree. A careful feries of experiments may however indicate the allowances neceffary to be made on both accounts, and in fmall depths the inftrument is fufficiently accurate

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on the principle already laid down. If this inſtrument were to be applied to meaſure conſiderable depths, the temperature of the ſubmarine regions would require to be found and allowed for.

R It is a well-known fact, that an empty veſſel, that is to ſay, a veſſel containing air, immerſed in water with the mouth downwards, will not become filled, becauſe the ſpring of the air will prevent the water from entering, as may be eaſily ſeen by the help of a wine-glaſs. The diving-bell is conſtructed on this principle. It conſiſts of a large veſſel, or kind of caſk, ſo loaded with lead as to ſink when empty, with the mouth downwards. In the top is fixed a cock to let out the air, and a ſtrong pane of glaſs to afford light to the divers, who ſit on a circular bench in the inſide. This machine is lowered into the water about twelve feet at a time, and at each pauſe air is ſent down in ſmaller bells to the divers, and by them received into the cavity of the great bell, for the purpoſe of expelling the water that enters as the preſſure condenſes the included air. After it has arrived at the bottom of the ſea, the operators continue by the ſame means to repleniſh the air which becomes foul by breathing, ſuffering the impure air to eſcape by the cock in the upper part, as they receive freſh air by the barrels or ſmall bells; ſo that by this contrivance they can remain under water as long as they pleaſe.

S The air-balloon is of two kinds; the one intended to contain heated air, and the other inflammable

flammable air. Hot air occupies more ſpace when colder (54, G), and inflammable air is much lighter at a given temperature than the common air of the atmoſphere. From this it follows, that any maſs of either heated or inflammable air, if at liberty, will aſcend in the atmoſphere with a force of buoyancy equal to the difference between its own weight and the weight of an equal bulk of common air (9, B). If the heated or the inflammable air be included in a bag, and the weight of the bag be leſs than the difference juſt mentioned, the bag will be carried upwards, though with a leſs degree of force, namely, with a force equal to the difference leſſened by the weight of the bag. This is commonly called an air-balloon; which, though its figure is not eſſential to its property of aſcending, we will ſuppoſe to be a globe. If the magnitude of a balloon be T increaſed, its power of aſcenſion, or the difference between the weight of the included air and an equal bulk of common air will be augmented in the ſame proportion; that is to ſay, in proportion to the cube of its diameter. But the weight of the covering or bag will not be increaſed in ſo great a proportion. For its thickneſs being ſuppoſed the ſame, it is as the ſurface it covers, or only as the ſquare of the diameter. This circumſtance is the cauſe why balloons cannot be made to aſcend, if under a given magnitude, with cloth or materials of the ſame thickneſs.

Fig.

u Fig. 146, reprefents the balloon firft invented. It confifts of an immenfe bag of canvas, or other cloth, painted with a compofition that may leffen its fufceptibility to take fire. A net covers the upper part of its furface, from which proceed ropes that fuftain a gallery to carry the adventurers and fuel. The lower part is affixed to the gallery, and open to receive the ftreams of heated and rarefied air, produced by means of fire maintained in an iron grate, fufpended in the middle of the orifice. The firft inflation of the balloon is effected by means of a fire made in a proper apparatus on the ground, and the attached grate ferves only to maintain the requifite degree of rarefaction, by furnifhing a fupply of heated air in the room of that which is gradually condenfed by cooling. It is afcertained from experiment, that the rarity of the air in thefe machines depends folely on its heat and its property of cooling flowly; and it is likewife eftablifhed with a confiderable degree of certainty, that the weight of the included air is at a medium, about two thirds of the weight of an equal bulk of the air of the atmofphere. This balloon is raifed or lowered while in the atmofphere, by increafing or diminifhing the fire.

v Small balloons of thin paper, raifed on this principle by the flame of a fponge, or ball of cotton dipped in fpirits of wine, have been exhibited in every part of Europe.

w The inflammable air-balloon, fig. 147, is preferable to the other, in the prefent early ftate of our

our knowledge. It is usually formed of thin silk varnished over. When filled with inflammable air, its tube of communication A is usually closed, so that the air is prevented from escaping. The adventurers are placed in a car or small vessel B, attached to the balloon by strings, proceeding from a net that covers its upper part. They carry bags of sand with them to serve as ballast, and the end of the tube of communication, as well as a string that by pulling may open a valve in the top of the balloon, are continued down into the car. By those means they have, for a limited time, the power of ascending or descending at pleasure. For the power of ascension is increased by emptying one or more sand-bags, or diminished by suffering the inflammable air to escape either by the tube or through the valve. It may be observed, that the inflammable air, on account of its greater lightness, will not descend through the tube of communication, unless either by its own expansion from heat, or by the diminished pressure of the atmosphere at great heights, it is made to escape while the balloon is fully inflated; but it will issue from the upper valve, when open, in all circumstances whatever.

The inflammable air produced in the large way, by the effusion of diluted vitriolic acid, on iron shavings or turnings, is rather less than one fifth of the weight of an equal bulk of atmospherical air. It is estimated that a cubic inch of iron gives a cubic foot of inflammable air, and the strong vitriolic

vitriolic acid, ſold in London, requires to be diluted by five times its bulk of water, for this experiment.

Y To give at pleaſure a progreſſive motion to air-balloons, in any required direction, is a problem of great importance in this newly diſcovered art of penetrating into the ſuperior regions of the atmoſphere. Many wild and abſurd ſchemes for this purpoſe have been offered to the conſideration of the public; and ſome that have been carried into effect have ſerved only to evince the ignorance or the artful quackery of their projectors. Little however of real value has been yet done towards accompliſhing this purpoſe. The grand difficulty of the attempt conſiſts in the large ſurface of reſiſtance expoſed to the ſurrounding fluid, which has hitherto been ſuch, that the quantity of air required to be diſplaced is ſo great, that the ſtrength of the voyagers cannot diſplace it with any conſiderable velocity; that is to ſay, when they have given a ſmall degree of velocity to the machine, the reſiſtance of the air becomes ſuch, that their whole ſtrength will be employed in over-
Z coming it, inſtead of adding to the velocity. The principal object therefore muſt be, to conſtruct the balloon of ſuch a figure as that it may move through the air without diſplacing any conſiderable quantity of it. As to the application of the ſtrength, it may be done by a variety of methods. It is required that it ſhould be exerted on the air in the oppoſite direction to that intended to be produced

in

in the balloon, and as no mechanism can bestow or create strength (1. 73, E) the simplest machine will be the best, because the loss by friction will then be least.

The uses to which machines of this kind may be applied are numerous, and will easily occur to any ingenious person. It will probably be long before the experiment will be performed in a sufficiently cheap way to admit of its being applied to the ordinary purposes of travellers. Its use on extraordinary occasions, for the conveyance of intelligence in military operations; for penetrating into places inaccessible by other means; or, for making philosophical observations on the superior regions of the atmosphere, are sufficiently obvious. We cannot, however, boast of any addition having been made to the stock of atmospherical knowledge, though very many aerial voyages have been performed. The probable causes of this are, that the balloons have seldom ascended above two miles high; that the novelty and grandeur of the scene beheld from a balloon has prevented a strict attention to the phenomena that may have presented themselves; and more especially, that most of the experiments were performed by ignorant and mercenary imitators, who have been much more desirous of taking the advantage of the surprize and credulity of the vulgar, than of making valuable observations, or relating them with fidelity. A

The invention of the heated air balloon is the undoubted right of the brothers, Messrs. Stephen

and John Mongolfier, who made the firſt experiment at Avignon in November, 1782. The firſt balloon raiſed in the atmoſphere by means of inflammable air, was conſtructed by public ſubſcription, opened by M. Faujas St. Fond at Paris. Meſſrs. Roberts were appointed to conſtruct the machine, and M. Charles to ſuperintend the work. It was launched from the Champ de Mars Auguſt 27, 1783. The firſt human being that aſcended into the air by means of an air-balloon was M. Pilatre de Rozier. He was afterwards accompanied by M. Gironde de Vilette, and afterwards by the Marquis d'Arlandes. The balloon uſed in theſe experiments roſe by heated air, and was conſtructed by John Mongolfier at Paris. It was prevented from eſcaping by ropes. The firſt aerial voyage was performed with the ſame balloon by M. Pilatre de Rozier and the Marquis d'Arlandes, who paſſed over the city of Paris November 21, 1783. The firſt aerial voyage with a balloon filled with inflammable air was made by Meſſrs. Charles and Robert from Paris December 1, 1783. They were carried about twenty-ſeven miles in one hour and three quarters. The great rarity of inflammable air was firſt aſcertained (in 1766) by Mr. Cavendiſh, and the idea of its application to the purpoſe of floating a bag in the atmoſphere was explained by Dr. Black in his lectures next following that period. Several philoſophers made attempts to carry this into effect previous to June 1782, and ſucceeded ſo far as to inflate ſoap-bubbles with inflam-

inflammable air, which rapidly aſcended to the ceiling of the room. But it is to the philoſophic ſpirit and liberality of our neighbours the French that we are indebted for this experiment being completely performed in the large way, without whoſe encouragement it might probably have long remained nothing more than a happy thought*.

On the 14th of June, 1785, the intrepid and ingenious Pilatre de Rozier fell a victim to the new art in which he was the firſt adventurer. He attempted to croſs the Britiſh channel in company with a gentleman, whoſe name was Romain. His balloon conſiſted of two parts: the upper contained inflammable air, and the lower part was a balloon for heated air. By this ingenious addition it was expected, that a power of aſcending or deſcending at pleaſure, without loſs either of ballaſt or of inflammable air, would have been obtained. When the unfortunate travellers were at the eſtimate height of about ſix thouſand toiſes, the upper balloon took fire near the top, and burſt. The apparatus immedirtely fell to the ground. Pilatre de Rozier firſt came to the earth: no ſigns of life were perceived in him, but his companion is ſaid to have uttered an exclamation before he expired.

This mueh lamented event is ſuppoſed to have ariſen either from the electricity of the clouds ſetting fire to the ſtream of inflammable air that

* For a further account of this ſubject, the Engliſh reader may have recourſe to Cavallo's Hiſtory and Practice of Aeroſtation.

issued from the upper valve, or from the inflammable air that escaped, forming a train of communication between the upper balloon and the fire beneath, which in its ascent was continually brought into the place before occupied by the balloon. This last opinion is rendered most probable, from the agitation and apparent distress observed in the travellers a short time before the catastrophe. They had prudently lowered the stove before Pilatre de Rozier opened the upper valve. The efflux of inflammable air occasioned by this last manœuvre was probably the immediate cause of their destruction*.

CHAP. VI.

OF THE AIR-PUMP AND ITS USES.

B THE air-pump is one of the most useful of all philosophical instruments, whose actions depend on the properties of the air. By the help of this machine, all that has been shewn concerning the weight and elasticity of the air, is demonstrated in the most simple and elegant manner. Its construction is as follows: E F G H (fig. 148) is a square table of wood, A A are two strong barrels or tubes of brass, firmly retained in their position by the piece T T, which is pressed on them by screws O O, fixed on the tops of the brass pillars N N. These barrels communicate with a cavity in the lower part

* See the Courier de l'Europe for July 1, 1785.

D. At the bottom within each barrel is fixed a valve, opening upwards, and in each a piſton works, having a valve likewiſe opening upwards. The piſtons are moved by a cog-wheel in the piece T T, turned by the handle B, and whoſe teeth catch in the racks of the piſtons C C. P Q R is a circular braſs-plate, having near its center the orifice K of a concealed pipe, that communicates with the cavity; in the piece D at V is a ſcrew that cloſes the orifice of another pipe, for the purpoſe of admitting the external air when required. L M is a glaſs-receiver, out of which the air is to be exhauſted. It is placed on the plate P Q R, firſt covered with a wet ſheepſkin, or ſmeared with wax, to prevent the air from inſinuating under the edge of the glaſs.

When the handle B is turned, one of the piſtons C is raiſed, and the other depreſſed; a void ſpace is conſequently left between the raiſed piſton and the lower valve in the correſpondent barrel: the air contained in the receiver L M, communicating with the barrel by the orifice K, immediately raiſes the lower valve by its ſpring, and expands into the void ſpace; and thus a part of the air in the receiver is extracted. The handle then being turned the contrary way, raiſes the other piſton, and performs the ſame act in its correſpondent barrel; while, in the mean time, the firſt mentioned piſton being depreſſed, the air, by its ſpring, cloſes the lower valve, and, raiſing the valve in the piſton, makes its eſcape. The motion of the handle being again reverſed, the firſt barrel again

exhauſts while the ſecond diſcharges the air in its turn: and thus, during the time the pump is worked, one barrel exhauſts the air from the receiver, while the other diſcharges it through the valve in its piſton.

D Hence it is evident, that the vacuum in the receiver of the air-pump can never be perfect; that is, the air can never be entirely exhauſted: for it is the ſpring of the air in the receiver that raiſes the valve, and forces air into the barrel, and the barrel at each exſuction can only take away a certain part of the remaining air, which is in proportion to the quantity before the ſtroke, as the capacity of the barrel is to that of the barrel and receiver added into one ſum.

E This, however, is an imperfection that is ſeldom, if ever, of any conſequence in practice, becauſe all air-pumps, at a certain period of the exhauſtion, ceaſe to act, on account of their imperfect conſtruction. For the valves uſually conſiſt of a piece of oiled bladder tied over a hole, ſo that the air is at liberty to paſs by lifting up the bladder, but cannot return again, and there will unavoidably be a ſmall ſpace left between the lower valve and the piſton when down. Now, it will happen, when the air in the receiver is very rare, that its ſpring will not be ſtrong enough to overcome the adheſion of the bladder forming the lower valve, which, conſequently, will remain ſhut, and the exhauſtion cannot proceed. Or, before this period, it may happen, that the air between the valves when the

piſton

piſton is up may be ſo ſmall as to lie in the ſpace between the two valves when the piſton is down, without being ſufficiently condenſed for its ſpring to overcome the adheſion of the bladder forming the upper valve, and the weight of the atmoſphere that preſſes it: in this caſe the upper valve will remain ſhut, and the exhauſtion cannot proceed. In the beſt air-pumps theſe imperfections are in a great degree removed. For the adheſion of the bladders is much diminiſhed, and the action of the air upon them increaſed, by ſubſtituting a number of large holes of paſſage, inſtead of one ſmaller. By cauſing the rod of the piſton to paſs through a collar of leathers, ſcrewed to the upper part of the barrel, and placing another valve for the paſſage of the extruded air, the preſſure of the atmoſphere is prevented from acting on the piſton, ſo that the whole ſpring of the air between the piſton and lower valve is exerted in overcoming the reſiſtance afforded by the valve of the piſton. There are alſo contrivances for opening a communication between the receiver and the barrel, without depending on the ſpring of the air. One of the beſt of theſe conſiſts in an additional piece that lifts the lower valve when a lever is preſſed with the foot: the lever communicates with the interior piece by means of a rod that paſſes through a collar of leathers at the lower end of the barrel*. The beſt ſort of air-pumps are uſually made with a ſingle barrel.

* This is the invention of one ——— Haas, a workman in London, who has taken out a patent for it.

In meaſuring the exhauſtion there are two methods of proceeding. The one ſhews the denſity of the air left in the receiver, without regarding ſuch vapours as may aſſume an elaſtic form in the vacuum: the other exhibits the ſpring of the elaſtic fluid in the receiver, without ſhewing whether it be permanently elaſtic air. The quantity of air is ſhewn by an inſtrument called the pear-gage. It conſiſts of a glaſs-veſſel in the form of a pear, with graduations near its upper end, that denote certain known parts of its bulk. This is included in the receiver, together with a veſſel of mercury, into which its mouth may be occaſionally plunged. When the exhauſtion is made, the pear-gage is plunged into the mercury, and the external air admitted into the receiver. The mercury riſes in the gage, and occupies the whole of its cavity, except a ſpace at top, poſſeſſed by a bubble of air, whoſe magnitude is known from the graduations, and is in proportion to the whole contents of the gage, as the quantity of air in the exhauſted receiver is to an equal volume of the common atmoſpherical air.

This gage would be accurate for all purpoſes, if it were not that moſt fluid or moiſt ſubſtances aſſume an elaſtic form when the preſſure of the atmoſphere is removed. For this reaſon it ſeldom indicates the elaſticity or actual preſſure of the fluid remaining in the receiver. The barometer gage is uſed for this purpoſe. If a barometer be included beneath a receiver, the mercury will ſtand at the ſame height

as in the open air; but when the receiver begins to be exhauſted, the mercury will deſcend, and reſt at a height which is in proportion to its former height as the ſpring of the remaining air is to its original ſpring before the exhauſtion. It is uſual to ſay, the air is as many times rarer than the atmoſphere, as the column it ſuſtains is leſs than the height the mercury ſtands at in a detached barometer. On account of the inconvenience of including a barometer in a receiver, a tube of ſix or eight inches length is filled with mercury, and inverted in the ſame manner as the barometer. This being included, anſwers the ſame purpoſe, with no other difference than that the mercury does not begin to deſcend till about three-fourths of the air is exhauſted. It is called the ſhort barometer gage. Others place a tube, of a greater length than the barometer, with its lower end in a veſſel of mercury, while its upper end communicates with the receiver. Here the mercury riſes as the exhauſtion proceeds, and the preſſure of the remaining air is ſhewn by the difference between its height and that of the barometer. This is called the long barometer gage.

These gages are not often conſtructed ſo as to H anſwer the purpoſe of ſhewing the degree of exhauſtion to a great degree. For the mercury, though at firſt boiled, to clear it of the air and moiſture that adhere to it, and render it ſenſibly lighter, gradually becomes again contaminated by expoſure to the air in the baſon of either gage. They cannot therefore with ſtrictneſs be compared

with

with a good barometer in which this does not happen. If the tubes of the gages be leſs than half an inch in diameter, the mercury will be ſenſibly repelled downwards, ſo as to require a correction for the long gage when compared with a barometer, whoſe tube is of a different bore, and to render the ſhort gage uſeleſs in great exhauſtions. Thus, for example, if the ſhort gage have a tube of one-tenth of an inch in diameter, the mercury will fall to the level of the baſon when the exhauſtion is 150 times, and will ſtand below the level for all greater degrees of rarefaction. Theſe difficulties may all be removed, by making the ſhort gage in the form of an inverted ſyphon, with one leg open, and the other hermetically ſealed. It muſt be confeſſed, however, that it is not eaſy to boil the mercury in theſe; and the method of doing it with ſucceſs cannot, with ſufficient conciſeneſs, be deſcribed here.

I Few air-pumps exhauſt to ſo great a degree as one thouſand times by the barometer gage; but the pear-gage in ſome circumſtances will indicate an exhauſtion of many thouſand times.

K Several of the uſes of the air-pump have already been mentioned. The weight of the air is ſhewn by exhauſting it out of a bottle (30, x) and its preſſure is proved to be the cauſe of the aſcent of the mercury in the barometer, becauſe in the vacuum it is no longer ſuſtained. It will be proper to ſubjoin a few more inſtances.

If a ſquare bottle, in whoſe neck is fixed a valve, L opening outwards, be placed under the receiver, and the air exhauſted, the bottle will be cruſhed to pieces by the weight of the atmoſphere when the air is permitted to return into the receiver. For the air is prevented from entering the bottle by the valve, which, before the exhauſtion, ſuſtained the preſſure of the atmoſphere on its external ſurface, by means of the ſpring of the included air acting equally on the internal ſurface; but in this experiment, being deprived of its internal air, it is incapable of bearing the weight of the atmoſphere, which preſſes it on all ſides. If the bottle were round inſtead of ſquare it would ſuſtain the preſſure, notwithſtanding the exhauſtion, by reaſon of its arched figure, that would prevent its giving way inwards.

The quantity of this preſſure on a given ſurface M is equal to the weight of a column of mercury, whoſe baſe is the given ſurface, and whoſe height is the height of the mercury in the barometer. (32, B) To exemplify and prove this by the air-pump, it is uſual to incloſe in the receiver two braſs hemiſpheres, as A and B (fig. 149), that ſhut together like a box, and at the place of ſhutting are lined with wetted leather. The air being exhauſted from the receiver, eſcapes likewiſe from the cavity of the hemiſpheres, and when it is permitted again to enter the receiver, the hemiſpheres are ſo cloſely preſſed together, that the air cannot enter at the place of junction: they adhere together

ther therefore, with a force equal to the preſſure of the atmoſphere, which is greater or leſs in proportion to the area of the circle at the place of junction. Thus, if the diameter of the circle where the hemiſpheres are joined be four inches, the force required to ſeparate them muſt exceed 230 lb. troy.

N Since bodies immerſed in fluids loſe parts of their weights, which are equal to the weights of maſſes of the fluids reſpectively equal in bulk to the bodies themſelves (8, z, A), it follows that bodies of different ſpecific gravities, which are in equilibrio in the air, will not remain ſo in vacuo. For in vacuo each body will re-acquire the weight they loſe while in the air, and the body, whoſe bulk is greateſt, will acquire the greateſt weight. Thus, if a piece of cork be in equilibrio with a piece of lead, when weighed by fine ſcales in the air, the cork will preponderate in vacuo; the removal of the air adding proportionally more to its weight, as its bulk exceeds that of the lead.

O The ſpring of the air may likewiſe be ſhewn in a variety of manners by the aſſiſtance of the air-pump. Suppoſe a ſmall tube to be inſerted through the cork of a bottle, half full of mercury, ſo that the communication between the air included in the upper part of the bottle and the external air ſhall be entirely cut off, the end of the tube being immerſed in the mercury. Let this apparatus be placed under the receiver, and the air exhauſted. The ſpring of the included air then preſſing on the ſurface

ſurface of the mercury, will force it into the tube, and ſuſtain it at the ſame height nearly as it ſtands in the barometer; for the ſpring of the air is equal to its weight (1. 22, R), and conſequently produces an equal effect: but on account of the imperfection of the vacuum, and the expanſion of the air in the bottle, by which its ſpring is weakened, the mercury does not riſe exactly as high as it does in the barometer.

If a half blown bladder be placed in the receiver, the included air will expand as the exhauſtion proceeds, and will blow it up even to burſting. And if this bladder be incloſed in a box, whoſe cover is loaded with weights ſomewhat leſs than equal to that of the atmoſphere, the expanſion will raiſe the cover and ſuſtain the weights. Thus, if the bladder be incloſed in a box of 6 inches diameter, it will raiſe the cover, though loaded with upwards of 500 lb. troy (32, B). P

The ſpring of the air included in the larger pores or veſſels of bodies, is the foundation of a number of pleaſing and inſtructive experiments. Thus it is found, that wood is ſpecifically lighter than water, only by reaſon of the ſpring of the air included in its veſſels, that prevents the water from entering: for when this air is extracted, and the water, by the admiſſion of the external air into the receiver, is impelled into the veſſels of the wood, it is always found to ſink to the bottom. Q

The refractive power of the air is alſo ſhewn by the air-pump. For if the air be exhauſted out of R

a priſmatic

a priſmatic glaſs-veſſel, the rays of light will not paſs ſtrait through its ſides, but, in paſſing through the vacuum, will be deflected according to the eſtabliſhed laws of optics. The proportions of the ſines of the angles of incidence and refraction, out of the vacuum into the air, are by this means found to be as 100036 to 100000, which is nearly the ſame ratio as is deduced from the refractions of the heavenly bodies.

s It is likewiſe proved by the air-pump, that the air is the medium of ſound. A bell or ſmall alarm clock, being rung in the exhauſted receiver, gives no ſound, but if the air be admitted, the ſound gradually becomes louder and louder, till the air in the receiver be of the ſame denſity with that of the atmoſphere, at which time the ſound is no otherwiſe weakened than on account of the receiver that covers the bell.

T The reſiſtance of the air is exhibited in a ſtriking manner by the help of the air-pump; for, if a guinea and a feather be let fall together from the top of a tall exhauſted receiver, they both arrive at the bottom at the ſame inſtant.

U Among the very numerous inſtances of the uſefulneſs of this inſtrument, we ſhall mention but two more; namely, the diſcovery of the abſolute neceſſity of air for the preſervation of life in moſt animals, and for the production and continuance of flame. Moſt animals, when included in the exhauſted receiver, are obſerved to die in about five minutes, though the time is various in different

ſpecies; and they moſtly recover again, if the air be again admitted without being withheld too long. A lighted candle placed under the receiver, is extinguiſhed at the beginning of the rarefaction, and the ſmoke hovers about the top of the receiver; but when the air is ſtill more rarefied, it becomes ſpecifically heavier, and ſubſides to the bottom.

BOOK III.

SECT. I.

Of Chemiſtry.

CHAP. I.

CONCERNING HEAT.

Every change that can take place in bodies is effected by means of motion. The buſineſs of natural philoſophy is to inveſtigate the cauſes of the ſeveral motions, and the laws they follow. In many inſtances theſe motions come under the inſpection of our ſenſes, but for the moſt part they are perform-ed among the minute parts of bodies, and are only known by the effects they produce. The foregoing part of this work has been chiefly confined to the explanation of the former kind of motions, which may be denoted by the general term mechanics. The latter, namely, the effects produced by motions among bodies too minute to affect the ſenſes individually, are the object of a ſcience called chemiſtry.

Heat is one of the moſt important and general cauſes of change in bodies. This term is commonly

monly uſed to denote as well the ſenſation cauſed by an increaſe of temperature in the human body as the ſtate in which inanimate bodies are when their temperature is increaſed. In the following pages, however, it will not be neceſſary to attend to the ſenſation. The word temperature will be uſed to denote the ſtate of a given ſolid, fluid, or vaporous body; with reſpect to heat; and the word heat will be uſed to denote the cauſe of that ſtate.

A body is ſaid to be hot or cold accordingly as w
its temperature is above or below a given ſtandard. The vulgar make uſe of the temperature of the human body as a ſtandard for this purpoſe. But this is by no means accurate enough for philoſophical purpoſes, becauſe the ſenſations of no two perſons agree, nor even thoſe of the ſame perſon at different times.

The dimenſions of a body are always increaſed x
with the temperature, ſo long as the body retains the ſtate of ſolidity, fluidity, or vapour, it happens to poſſeſs, and has ſuffered no change either in the combination or quantity of its chemical principles. This is the chief, and, perhaps, the only general criterion by which the changes of temperature can be appreciated.

Bodies in contact, or that communicate with each y
other, will all acquire one and the ſame temperature, after a certain length of time, however different their reſpective original temperatures may have been.

There are two opinions concerning heat. According- z
ing to one opinion, heat conſiſts in a vibratory mo-

tion of the parts of bodies among each other, whoſe greater or leſs intenſity occaſions the increaſe or diminution of temperature: according to the other opinion, heat is a ſubtile fluid that eaſily pervades the pores of all bodies, cauſing them to expand by means of its elaſticity, or otherwiſe. Each of theſe opinions is attended with its peculiar difficulties. The phenomena of heat may be accounted for by either of them, provided certain ſuppoſitions be allowed to each reſpectively; but the want of proof of the truth of ſuch ſuppoſitions renders it very difficult, if not impoſſible, to decide, as yet, whether heat conſiſts merely in motion or in ſome peculiar matter.
A The word quantity applied to heat will therefore denote either motion or matter, according to the opinion made uſe of, and may be uſed indefinitely without determining which.

B Whatever heat may be, it is certainly lawful to affirm, that when the temperatures are the ſame, the quantities of heat are equal in equal bodies of the ſame kind; thus, a pound of gold contains an equal quantity of heat with another pound of gold at the ſame temperature, a pound of water contains an equal quantity of heat with another pound of water at the ſame temperature, &c. Hence it follows, that the quantity of heat in two pounds of a given ſubſtance is twice as much as is contained
C in one pound at the ſame temperature; and univerſally in homogenous bodies of the ſame kind, the quantities of heat will be as the maſſes, provided the temperatures be the ſame.

If two bodies that differ only in temperature be brought into contact, they will (113, Y) acquire a common temperature, and the quantity of heat in each will be equal (114, B). It is therefore seen, that the hotter body has imparted half its surplus of heat to the other; and consequently the quantity of heat in one of the two bodies will be an arithmetical mean between the quantities originally contained in them. D E

If two bodies of the same kind that differ in magnitude and temperature be brought into contact, they will (113, Y) acquire a common temperature, and the quantity of heat in each will be (114, C) in proportion to the masses: that is to say, the quantity of heat which caused one of the two bodies to be hotter than the other will be divided between them in proportion to their masses. F G

The quantities of heat required to be imparted to, or subducted from, bodies of the same kind, in order to bring their temperature to any given standard, will consequently be as their masses. H

On these considerations it is that the thermometer is presumed to acquire the same temperature as the body it touches. For the mass of the thermometer ought to be very small in proportion to that of the body it is applied to; in which case the quantity of heat it gives out or receives in the acquisition of the common temperature will be so small as not sensibly to affect the body under consideration; so that the common temperature may be I

be taken inſtead of the original temperature required to be found.

K The arithmetical mean temperature between two equal bodies of the ſame kind, as determined by experiment (115, E) will cauſe the mercury in a thermometer to ſtand very nearly at an intermediate equal diſtance between the ſtations it would have had at the original temperatures of the two L bodies. The increments of expanſion in mercury are therefore very nearly as the quantities of heat M that cauſe them. And the quantities of heat added to, or ſubducted from, a given body in contact with a mercurial thermometer, will be expreſſed by the number of degrees the thermometer riſes or falls.

N Thus far the temperature and heat of bodies of the ſame kind have been chiefly conſidered; but if two equal bodies of different kinds and temperature be brought into contact, the common temperature will ſeldom, if ever, be the mean between O the two original temperatures; that is to ſay, the ſurplus of heat in the hotter body will be unequally divided between them, and the proportions of this ſurplus retained by each body will expreſs their reſpective diſpoſitions, affinities or capacities for heat.

P If therefore a given ſubſtance, as for example fluid water, be taken as the ſtandard of compariſon, and its capacity for heat be called one, or unity, the reſpective capacities of other bodies may be determined by experiment, and expreſſed in numbers in the ſame manner as ſpecific gravities uſually are.

And

And becauſe it is eſtabliſhed as well from reaſon as experiment, that the ſame capacity for heat obtains in all temperatures of a given body, ſo long as its ſtate of ſolidity, fluidity, or vapour, is not changed; it will follow, that the whole quantities of heat in equal bodies of a given temperature will be as thoſe capacities. And as the reſpective quantities of matter in bodies of equal volume give the proportions of their ſpecific gravities, ſo the reſpective quantities of heat in bodies of equal weight and temperature give the proportions of their ſpecific heats. Q R

A greater capacity for heat, or greater ſpecific heat in a given body, anſwers the ſame purpoſe with reſpect to temperature as an increaſe of the maſs; or (115, H) the quantity of heat required to be added or ſubducted, in order to bring a body to a given temperature, will be as its capacity or ſpecific heat (117, R). S

The capacities not only differ in various bodies, but alſo in the ſame body, accordingly as it is either in a ſolid, fluid, or vaporous ſtate. All the experiments hitherto made conſpire to ſhew, that the capacity, and conſequently the ſpecific heat, is greateſt in the vaporous, leſs in the fluid, and leaſt in the ſolid ſtate. T

The quantity of heat that conſtitutes the difference between the ſeveral ſtates may be found in degrees of the thermometer. Thus, if equal quantities of water at 162°, and ice at 32° of temperature, be mixed, the ice melts, and the common U

temperature becomes 32°; or otherwise, if equal quantities of frozen and of fluid water, both at the temperature of 32°, be placed in a like situation to acquire heat from a fire, the water will become heated to 162°, while the ice melts, without acquiring any increase of temperature. In either case the ice acquires 130° of heat, which produces no other effect than rendering it fluid. Fluid water therefore contains not only as much more heat than ice, as is indicated by the thermometer, but also 130°, that is in some manner or other employed in giving it fluidity. And as fluid water cannot become ice without parting with 130° of heat, besides what it had above 32° in its temperature; so also steam cannot become condensed into water without imparting much more heat to the matters it is cooled by than water at the same temperature would have done.

v The heat employed in maintaining the fluid or vaporous form of a body, has been called latent heat, because it does not affect the thermometer.

w From the consideration of the specific heats of the same body in the two states of solidity and fluidity, and the difference between those specific heats, is deduced a method of finding the number of degrees which denote the temperature of any body immediately after congelation, reckoned from the natural zero, or absolute privation of heat. The rule is; multiply the degrees of heat required to reduce any solid to a fluid state by the number expressing the

the specific heat of the fluid: divide this product by the difference between the numbers expressing the specific heat of the body in each state; the quotient will be the number of degrees of temperature, reckoned from absolute privation of heat*.

To give an example of this curious rule, let it be required to determine how many degrees of refrigeration would absolutely deprive ice of all its heat? The degrees of heat necessary to melt ice are 130,

* This theorem is Dr. Irvine's, and may be proved thus; let s represent the required temperature of the body just congealed, l = the number of degrees that express the heat required to reduce it to fluidity, n = the specific heat of the solid, and m = the specific heat of the fluid. Then, $s + l : s :: m : n$. Whence $s = \frac{l\,n}{m-n} =$ the temperature from the natural zero in thermometrical degrees of the fluid (117, u). But because the actual fall of the thermometer is to be produced by cooling the solid, we must pay attention to its capacity (117, s). The quantity of heat required to produce a given change of temperature in a body is as its capacity, and consequently the changes of temperature, when the quantity of heat is given, will be inversely as the capacities: therefore $n : m :: \frac{l\,n}{m-n} : \frac{l\,m}{m-n} = s$. Which is the rule given in the text.

If the data l, m, and n, be accurately obtained by experiment in any one instance, and the difference between the zero of Fahrenheit's scale and the natural zero be thence found in degrees of that scale, this difference will serve to reduce all temperatures to the numeration which commences at the natural o. So that s being known in all cases, if any two of the quantities l, m, or n, be given in any body, the other may be likewise had. For $l = \frac{s\,m - s\,n}{m}$. And $m = \frac{s\,n}{s - l}$. And $n = \frac{s\,m - l\,m}{s}$.

and the specific heats of ice and water are as 9 to 10. The number 130, multiplied by 10, produces 1300, and divided by the difference between 9 and 10 quotes 1300: therefore if ice were cooled 1300 degrees below 32°, or to—1268 of Fahrenheit's scale, it would retain no more heat.

Z It is unnecessary to point out the many physical causes that prevent either the production or mensuration of this ultimate degree of cold.

A Experiments on heat may be made by mixing fluid bodies, by placing them in a vase, whose temperature, volume, and specific heat or capacity are known; or by placing them in contact with ice at 32°; in which last case, the quantity of ice melted by a body hotter than 32° will be in proportion to the quantity of absolute heat that causes this difference of temperature.

B Much care is required to prevent occasional circumstances from influencing the results of these experiments. The masses, specific heats and temperatures of the vessel and thermometer made use of, as well as the temperature of the surrounding atmosphere, must be attended to. The thermometers must be very sensible, and give the temperature to tenths of degrees. The temperature of the mixture must be taken in various parts of the vessel, and its rate of cooling ascertained at different periods, in order to infer the common temperature that would have taken place if the surplus of heat could have been equally diffused at the first instant of the mixture. When the melting of ice

is

is made uſe of, it is neceſſary that the ice expoſed to the contact of the heated body ſhould be defended from the action of the external air, by being included in a veſſel ſurrounded on all ſides with other ice at 32°, and the temperature of the room ought not to be much colder than 32°, leſt the melted ice ſhould be again frozen, inſtead of running into the veſſel prepared to receive it.

The chief advantage which the opinion that heat C is cauſed by mere vibration poſſeſſes, is its great ſimplicity. It is highly probable that all heated bodies have an inteſtine motion or vibration of their parts; and it is certain that percuſſion, friction, and other methods of agitating the minute parts of bodies will likewiſe increaſe their temperature. Why, then, it is demanded, ſhould we multiply cauſes, by ſuppoſing the exiſtence of an unknown fluid, when the mere vibration of parts, which is known to obtain, may be applied to explain the phenomena? To this it is anſwered, that mere motion will not D apply to the phenomena: for, among other facts, water at 32° contains more heat than ice at 32°, and ought therefore to poſſeſs more vibration, yet it does not communicate more to the thermometer. A part of its motion muſt conſequently be latent or incommunicable, which is an abſurdity.

A happy explanation of the manner in which the E temperature of a body is raiſed by friction or percuſſion, has been given* on the ſuppoſition that heat is matter. If the parts of a body containing any

* By Mr. Kirwan.

fluid be made to vibrate ſtrongly and irregularly, they will expel a part of the fluid out of the pores, provided the fluid be not ſufficiently compreſſed to move in correſpondence with the vibrations. For in this caſe a vibrating particle may be conſidered as if its dimenſions were encreaſed, which is in effect the ſame thing as if the pores of the body were diminiſhed. The capacity of the body will thus be diminiſhed, and conſequently its temperature will be increaſed (117, S).

F All the changes of temperature from the moſt intenſe cold to the utmoſt violence of ignition may be explained from the changes the capacities of bodies, and conſequently their ſpecific heats,
G undergo in the ſeveral chemical proceſſes. For univerſally, whenever the capacities of bodies are diminiſhed, either by freezing or condenſation, (117, T) by friction or percuſſion, (121, E) or by a change in the chemical combination, then the temperature is increaſed (117, S). And on the contrary, the temperature is diminiſhed, or bodies become cold whenever their capacities for heat are increaſed.

H Thus, in the ſolution of various ſaline bodies in water, cold is produced; becauſe the capacity of the ſalt being increaſed (117, T) by its becoming fluid, while the abſolute quantity of heat remains the ſame, its temperature muſt be diminiſhed (117, S). Conſequently, the common temperature of the melted ſalt and water muſt be lower than it would have been if the ſalt had not been diſſolved (113, Y).

For

For the ſame reaſon a mixture of ſnow and ſalt, I
applied at the outſide of a veſſel containing water, produces a degree of cold that congeals the water, or would cauſe a thermometer to fall far beyond the freezing point. The ſnow and ſalt are rendered fluid by their mutual action on each other; their capacities for heat are increaſed, their temperatures conſequently diminiſhed, and the water frozen by the loſs of the heat it imparts to produce a common temperature.

So likewiſe, if a ſmall glaſs veſſel, containing K
water, be conſtantly wetted on the outſide with ether, the quick evaporation of this laſt fluid will produce a degree of cold that will in a very ſhort time freeze the included water. For the ſpecific heat of the ether, when converted into vapor, is ſo great, that its temperature becomes very low, and cools the water even below freezing.

The inſtances of cold produced by evaporation L
are exceedingly numerous. From this cauſe it is that water is commonly about two degrees colder than the ſurrounding air; that damp clothes produce ſuch chilling effects; that a wet hand, even though wetted with warm water, ſoon becomes colder than the other that remains dry, &c. &c.

The ſpecific heat of atmoſpherical air is found M
by experiment to be conſiderably greater than that of air which is expired from the lungs of an animal. The air therefore undergoes a change in the lungs, which diminiſhes its capacity and muſt conſequently increaſe its temperature. It is found alſo, that the

the capacity of blood for heat is diminiſhed in its courſe from the arteries to the veins. From theſe cauſes the temperature of the animal is continually increaſed. But the evaporation of perſpirable matter increaſes with the temperature, and produces cold. The equilibrium of theſe actions appears to be the reaſon why the temperature of any one ſpecies of animal is nearly the ſame in all climates. Animals that have no lungs are of the ſame temperature as the ſurrounding medium. In cold countries the effects of perſpiration, and the contact of the circumambient air are rendered leſs by the clothing, as thick fur, hair, &c. that envelope the native animals, and are from neceſſity made uſe of by the human ſpecies.

N The ſpecific heat of combuſtible matter is not conſiderable; the ſpecific heat of atmoſpheric air is much greater than that of air which has ſerved the purpoſe of combuſtion. Suppoſe now that by any means the temperature of a combuſtible ſubſtance be raiſed to ſuch a degree as that the chemical proceſs, which changes the capacity of the air, may go on, the temperature of the air will be raiſed in proportion as its capacity is diminiſhed, its heat will be imparted to, and ſtill more increaſe the temperature of the combuſtible body. A very high degree of temperature will be produced, which will be greater in proportion to the ſpecific heat of the air, the quantity decompoſed in a given time, and leſs in proportion to the facility with which it is abſorbed or conducted away

by

by other bodies. This proceſs is called combuſtion, when it is carried on with ſuch rapidity as to cauſe the body to emit light, at which time it is ſaid to be ignited; and it will continue till the principles of the body are ſo changed or diſſipated as that it can no longer make any change in the capacity of the ſurrounding air.

The friction of one piece of wood againſt another, in a turner's lathe, produces heat and flame. o A nail may be hammered till it becomes red hot. When flint and ſteel are ſtruck together, minute portions of the ſteel are knocked off, in ſo high a degree of heat, that they are actually burned, and upon extinction are ſeen, with the magnifier, to conſiſt moſtly of hollow balls of a black or greyiſh metallic colour, and about the one hundredth of an inch in diameter. When the ſun's rays are thrown, by a burning-glaſs or mirror (1. 325, N), on any ſubſtance, they exceedingly increaſe its temperature, and produce the moſt aſtoniſhing effects. In all theſe phenomena the temperature ſeems to be raiſed, at leaſt in the beginning, by the diminution of capacity, which is a conſequence of the agitation of the minute parts of bodies.

When water, or any fluid, is heated, the quantity evaporated in a given time becomes greater, P becauſe the heat which the greater capacity of ſteam demands is more readily ſupplied. The greater evaporation diminiſhes the augmentation of temperature the fluid acquires, and at a certain period entirely deſtroys it. This period or tempera-

ture,

ture, called the boiling point, is lower, the more easily evaporable the fluid, and will vary in the same fluid, accordingly as the evaporation is more or less easily performed. Thus spirit of wine boils at 180°, water at 212°, mercury at 600, and other liquids at other points respectively, at which they acquire the greatest heat they are capable of sustaining without being converted into vapor in the open air of a mean density. But if the evaporation be impeded, either by the fluid being included in a closed vessel, or by the increased pressure of a denser atmosphere, the fluid will acquire a higher temperature; and, on the contrary, if the atmosphere be light, or the fluid heated in vacuo, the boiling temperature will be lower*.

* The theory of heat, as here explained, is due to the immortal Dr. Black, and has been improved and illustrated by Dr. A. Crawford, Dr. Irvine, Mr. Kirwan, Professor Wilkie, Mr. Watt, Mr. Magellan, &c.

CHAP.

CHAP. II.

A DESCRIPTION OF THE METHODS OF APPLYING HEAT TO CHEMICAL PURPOSES.

THERE are few ſubſtances found in a natural ſtate whoſe conſtituent parts cannot be ſeparated from each other by the methods uſed in chemiſtry. One of the principal methods conſiſts in altering the temperature of bodies. Q

A great number of bodies are found to be capable of the ſolid, the fluid, and the vaporous or highly elaſtic form, accordingly as they contain leſs or more heat. The temperature at which ſolids become fluid is exceedingly various in different ſubſtances, as is likewiſe the temperature at which the internal parts of fluids begin to take a vaporous form, and eſcape with ebullition. The number of degrees of temperature comprehended between theſe two points of freezing and boiling is not governed by any relation yet diſcovered between theſe phenomena and the other properties of bodies. Thus mercury freezes at 49° below 0, and boils at 600°; the interval being 649°; water freezes at 32°, and boils at 212°, the interval being 180°; ſpirit of wine freezes at 52° below 0, and boils at 180°, the interval being 232°. It is probable that all bodies whatſoever are capable of the three ſtates of ſolidity, fluidity, and vapor; but that in many inſtances the R S

the freezing or boiling points may lie at temperatures not obtainable by any means in our power.

T Bodies that assume the vaporous state at a lower temperature are called volatile, when compared with such as require a greater degree of heat for the same purpose. Such bodies as either cannot be made to rise in vapor, or require an intense heat to raise them, are called fixed.

U It is easy to conceive how the parts of bodies may be separated from each other by change of temperature. Thus, if soap be dissolved in spirits of wine, and the temperature be rendered lower, the soap will assume a concrete form, and be separated long before the fluidity of the spirits can be affected. Water mixed with spirits is converted into ice by cold, and separated for the same reason. Again, if a mixture of copper and lead be exposed to a heat gradually increased, the lead will be melted first, and will run from the copper, leaving it in the form of a porous mass: or if brass, which is a mixture of copper and a volatile semi-metal called zink, be exposed to a considerable heat, the zink assumes the vaporous state, and leaves the copper alone. So likewise quicksilver is separated from gold, water from clay, &c.

V The purposes of chemistry are in general much better answered by raising than by lowering the temperature of bodies. The most usual method of heating bodies is, to place them in communication with others in a state of combustion; that is to say, place them near a fire. The vessels and

 furnaces

furnaces made uſe of are various, according to their ſeveral applications.

When ſubſtances of conſiderable fixity are to be expoſed to heat, or when the volatile parts of bodies are propoſed to be diſſipated into the air, open veſſels are uſed. The common culinary utenſils of copper or iron anſwer theſe intentions where the matter to be operated upon will not corrode them, and the heat is not required to be very great. Glaſs veſſels are the moſt cleanly, and may be uſed in a great variety of proceſſes. They have the advantage of reſiſting the action of moſt corroding matters, are impermeable to air and vapor, and their tranſparency affords the valuable convenience of beholding the changes that happen within them. In higher degrees of heat, ſuch as would ſoften or melt glaſs, it is neceſſary to uſe veſſels of earth, or other matter.

A mattras, is a kind of bottle ſhaped moſt commonly like a Florence flaſk, though its figure is various, according to the uſes it is intended to be applied to, fig. 150, letter c. A cucurbit, is a veſſel nearly of the ſame figure, but with a long neck, fig. 150, letter A. It is made either of metal, glaſs, or earthen-ware. A crucible, is a pot made uſe of for melting metal and other ſimilar purpoſes. It is made either of platina*, forged iron, black lead, or

* Mr. Achard's proceſs for making crucibles of platina is as follows: Take equal quantities of platina, white arſenic and

or earth. A cupel, is a ſhallow crucible, made of calcined bones, and uſed by aſſayers. The large crucibles of this kind, uſed by refiners, are called teſts.

Y In moſt operations where the volatile parts of bodies are propoſed to be ſeparated and preſerved, it is neceſſary to uſe cloſed veſſels. To the cucurbit A, fig. 150, is adapted the head B, denoted by the dotted line: from the head proceeds a tube that communicates with the mattras C, which in this caſe is called the receiver. The head B is incloſed within a tub or veſſel, called the refrigeratory. The whole apparatus thus diſpoſed is called an alembic or ſtill. The matter to be operated on is put into the cucurbit A, and the head fitted on: cold water is poured into the refrigerator; and the receiver adapted to the tube, by means of an earthy paſte, called lute. The fire being then lighted, forces the volatile fumes into the head B, where they become condenſed by the cold, and flow in a liquid form into the receiver C. This proceſs is called diſtillation.

Z When diſtillation is performed in the large way, a very large tub or veſſel is ſubſtituted inſtead of

and ſalt of tartar, and expoſe them to a ſtrong heat, till they melt. This matter, when cooled, muſt be reduced to powder, with which the mould of the veſſel intended to be formed muſt be filled. A ſtrong heat quickly raiſed, under a muffle, and continued for ſome time, will again fuſe the maſs: the arſenic and ſalt of tartar will be forced off, and the platina will be left alone in the form deſired.

the

the refrigerator, and the vapors paſs through a ſpiral pipe called the worm. Thus fig. 151, A is the body of the ſtill, B the head, D the worm-tub containing cold water, and the dotted lines repreſent the pipe called the worm, terminating at E, where the condenſed vapors run out in a liquid form.

But there are many matters required to be di- A
ſtilled that are not ſufficiently volatile to paſs into the receiver by either of theſe methods. In ſuch caſes the refrigerating part is omitted, and the cucurbit is made with its neck on one ſide, as in fig. 152. It is then called a retort, and the receiver is uſually luted to the neck. Moſt of the experiments made in the ſmall way may be performed with retorts, if attention be paid to apply more or leſs heat, according to the volatility of the products expected to come over.

When volatile ſubſtances are raiſed by heat in a B
dry form, the proceſs is called ſublimation. If the ſublimed maſs has a looſe powdery form, it is called flowers. Such are the flowers of brimſtone, of benjamin, &c. An ordinary cucurbit, or mattras, will ſerve for the ſublimation of ſuch bodies as are not very volatile. When they are more volatile, the head B of the alembic is a proper receptacle, fig. 150, eſpecially if moiſt products ariſe and are required to paſs at the ſame time into the receiver C. In other caſes the receiver is not annexed, and a number of heads are fixed one above the other communicating by necks, the

uppermoſt one only being cloſed at top. Many ſublimates are attached to the chimnies of furnaces, among which common ſoot is a familiar inſtance.

c The conſtruction of furnaces is as various as the purpoſes they are deſigned to ſerve. A lamp, ſupported at different diſtances below any chemical veſſel, or burning with a variable number of wicks, is very uſeful where low degrees of heat are intended to be applied. Chemical veſſels may be plunged to greater or leſs depths in a pot over the fire containing either water, mercury, a mixture of mercury and lead, ſand, iron filings, or other matter capable of ſuſtaining heat. Theſe ſubſtances, interpoſed between the veſſel and the fire, compoſe what is called a bath, and are of excellent uſe for imparting an uniform heat, not ſubject to the ſudden viciſſitudes experienced by veſſels expoſed to a naked fire. Without this contrivance glaſs veſſels would often fly or crack. Glaſs or earthen veſſels, intended to ſuſtain a greater heat than can be given by means of a bath, are uſually* coated with a mixture conſiſting chiefly of clay and ſand.

* The valuable method uſed by Mr. Willis, of Wapping, to ſecure or repair his retorts uſed in the diſtillation of phoſphorus, deſerves to be mentioned here. The retorts are ſmeared with a ſolution of borax, to which ſome ſlaked lime has been added, and when dry, they are again ſmeared with a thin paſte of ſlaked lime and linſeed oil. This paſte being made ſomewhat thicker, is applied with ſucceſs during the diſtillation, to mend ſuch retorts as crack by the fire.

Fig.

Fig. 153, repreſents the wind-furnace, or air D melting furnace. In this ſection A denotes the aſh-hole, B the grate, C a crucible placed on the grate, F a ſtone covering the upper part of the fire-place, G the ſide-communication between the fire and the chimney E H. D is a cupel occaſionally placed in the current of flame that iſſues from the fire. The fuel and pots are introduced at the hole F. The effects of this furnace are eaſily explained. Combuſtion (124, N) is more rapid and intenſe in proportion to the quantity of air ſupplied and decompoſed. The preſſure of the atmoſphere upwards at B is greater than the preſſure of the column that acts downwards, becauſe the lower part of this laſt mentioned column conſiſts of a rarefied portion of air included in the cavity D C G E H. The lighter column will therefore aſcend with a velocity ſo much the greater as its rarefied part is longer and more rarefied. If therefore the fire be large, and the chimney high and ſufficiently narrow for the air to paſs through before it is much cooled, a very powerful degree of heat will be produced.

Fig. 154, repreſents the reverberatory furnace. E By means of the dome B the flames are driven back, and made to play round the retort C; and occaſionally the fuel may be heaped round the retort, ſo as nearly to fill the dome.

There are many other furnaces, for the making F of glaſs, the roaſting of ores, and extracting their contents, the firing of pottery, and other nume-

rous purpoſes. For the deſcription and uſe of theſe, larger treatiſes muſt be recurred to. The philoſophical chemiſt may in general perform his operations without being under the abſolute neceſſity of uſing furnaces conſtructed on purpoſe, or preparing any large apparatus of veſſels. A tobacco-pipe is a very uſeful kind of crucible, with which many experiments may be well made in a common fire, eſpecially with the aſſiſtance of a pair of double bellows. Common chafing diſhes, ſmall iron ſtoves, or the larger kind of * black lead pots may be applied to purpoſes of the moſt extenſive utility by an ingenious operator. Bottles of various ſhapes, and other veſſels, may be found in common uſe well ſuited to the performance of chemical experiments: ſuch are apothecaries phials, Florence flaſks, earthen pans, &c.

The blow-pipe is an inſtrument of great uſe in the chemical examination of mineral bodies. This may be procured in the ſhops, and conſiſts of a tube of about ten inches long, formed as in the figure (fig. 155). The aperture A is about a quarter of an inch in diameter, and is intended to be applied to the mouth in blowing; the other aperture B is very ſmall, ſo that the wind iſſues out in a fine ſtream. If now a candle be ſnuffed, and the wick turned a little on one ſide, the flame may, by this ſtream of air, be directed upon any ſmall

* The method of conſtructing cheap and portable furnaces out of black lead pots, is deſcribed at large in "Lewis's "Philoſophical Commerce of Arts."

body,

body, and is ſufficiently active to produce every change that the ſtrongeſt furnace can effect on larger bodies.

The common blow-pipe is ſubject to two prin- H
cipal inconveniences; the firſt is, that the moiſture of the breath becomes condenſed in the tube, and occaſionally ſpirting out of the aperture B, either checks the burning of the flame, or produces other diſagreeable accidents; the other is, that the aperture B being invariable, can only be adapted to a flame of one particular magnitude, whereas a larger flame requires a larger aperture. The blow-pipe beſt ſuited to philoſophical purpoſes is provided with a ball C (fig. 156) in which the vapors are detained, inſtead of paſſing through the aperture B: and the piece B may be unſcrewed, and changed for another, accordingly as the aperture is required to be varied. If the aperture be not round and ſmooth, the flame will be ragged and irregular.

The body to be urged by the flame, directed I
and excited by a blow-pipe, ought not to exceed the ſize of a grain of pepper. The beſt ſupporter to place it on is a ſmooth cloſe piece of charcoal, which anſwers perfectly well for all matters that do not ſink into its pores, nor are changed by its inflammable principle. In ſuch caſes as the charcoal cannot be uſed, it is neceſſary to be provided with a ſmall ſpoon, either of pure gold or pure ſilver, there being no other metals that admit of being worked with facility, but are changeable by heat.

K The advantages attending experiments made with the blow-pipe are many. They may be made in a very ſhort time in any place, by an apparatus that admits of being carried in the pocket. The quantity required of any material is ſo ſmall, that they are performed at a very little expence. And the whole proceſs, inſtead of being carried on in an opake crucible, is viſible from beginning to end. They are therefore of great utility in examining bodies where experiments in the large way cannot eaſily or conveniently be made, and where they can, theſe ſmall trials previouſly made are often of ſervice to indicate the beſt way of conducting them*.

L If the blow-pipe be uſed with the pure air, called dephlogiſticated air, obtained by diſtillation from nitre, or other ſalts, it produces a greater degree of heat than can be obtained by any other method yet diſcovered, unleſs we may except the heat in the focus of a few of the moſt capital burning lenſes.

M The burning glaſs or mirror is ſeldom uſed in chemiſtry, except on ſuch occaſions as do not admit of the other methods of heating bodies.

* The uſe of the blow-pipe is explained by Guſtav von Engeſtrom, in a treatiſe annexed to the Engliſh edition of Cronſtedt's Mineralogy, and alſo by Bergman, in his Treatiſe de tubo ferruminatorio, in which the habitudes of a great number of bodies in the fire, either with or without addition, are given. The Engliſh reader will find this excellent work at the end of Cullen's Tranſlation of Bergman's Eſſays. London. 1784.

CHAP. III.

AN EXPLANATION OF THE NATURE AND EFFECTS OF THE ELECTIVE ATTRACTION, OR CHEMICAL AFFINITY.

It has been ſufficiently ſhewn in the former parts A
of this Treatiſe, that the parts of bodies have a tendency towards each other, which is generally denoted by the word Attraction. Were it not for the effects of this power, the motions of all bodies would be performed in right lines (1. 21, P), and their parts would be ſeparated from each other by the ſmalleſt impulſe. It is, in fact, impoſſible to form a notion how the univerſe could ſubſiſt in its preſent form without it.

The firſt rule of philoſophizing (1. 6) leads us B
to enquire whether the various effects of attraction that take place in natural phenomena be conſequences of one and the ſame principle, or, if more cauſes than one ſhould be concerned in producing them, how far the operation of each extends. If the attraction of coheſion were the ſame as gravitation, its power would follow the ſame ratio of the diſtances of bodies from each other (1. 207), and would be ſenſible at very conſiderable intervals of
ſpace; but as it is perceived only at extremely C
ſmall diſtances, and even gives place to repulſion when the interval is increaſed (1. 47. Z), it ſeems neceſſary to conſider it as a diſtinct property of matter,

matter, or, at leaſt, as the effect of ſome other cauſe.

D Whether the attraction of coheſion, or the power that reſiſts the ſeparation, by mechanical means, of the parts of ſolid bodies, be the ſame as thoſe attractions which, on account of their being exerted more ſtrongly between two given bodies, than between one of the two and a third of a different kind, are called elective attractions, or chemical affinities, has not been well decided. The enumeration of a few ſimple propoſitions reſpecting attraction, generally conſidered, may tend much to elucidate this buſineſs.

E As the attraction of gravitation is taken to be a general property of matter, acting according to the maſſes of bodies (I. 18. I; 26, A), and we do not ſuppoſe a variety of attractions, but of denſities, in bodies that are variouſly heavy, ſo may one general property cauſe the particles of bodies to adhere together, though its intenſity, varying with the denſity of thoſe particles, may produce various effects.

F In all the phenomena of attraction, the force is greater when the diſtance is leſs: and it is clear, that particles of the ſame maſs and denſity may have various figures, ſome of which will admit of a nearer approach of their centers, when their ſurfaces

G are in contact, than others. Such particles as by their figure can admit of their centers coming nearer together, will adhere more ſtrongly on that account.

H Againſt the truth of the poſition, that the attractions diſplayed in the coheſion of bodies, and in

chemical operations, follow the denſity of the par-
ticles, it is no objection to ſay, that the hardneſs
and ſpecific gravity of bodies are governed by no
common law: for the hardneſs, according to this I
doctrine, depends on the denſity, magnitude, and
figure of the particles, and the ſpecific gravity on
the denſity of the particles, and the proportion be-
tween their aggregate bulk and the bulk of the
ſpace occupied by the pores of the bodies. And K
as theſe attributes do not depend on each other, but
may vary indefinitely, there is no neceſſary relation
between hardneſs and ſpecific gravity.

The adheſion of like parts, by which a body is L
formed of the ſame kind as the parts themſelves, is
called aggregation; but the adheſion of parts, not
of the ſame kind as each other, by which a body
is formed, having properties different from thoſe
of the parts, is called combination. It does not M
appear that combination is performed by any power
different from the attraction of coheſion, by which
aggregation is allowed to be produced; or, in other
words, the attraction of coheſion, and of chemical
affinity, appear to be the ſame power exerciſed in
different circumſtances.

If a particle of matter be ſurrounded by others of N
a certain kind in contact with it, it may ſtill
attract and retain others, forming a ſecond envelop-
ing ſtratum, and ſo on, according to the force of
attraction it exerts on ſuch particles. But at a cer-
tain period the accumulation will ceaſe, on account
of the attraction being inconſiderable beyond a

limited

O limited distance. At this period, if particles of a third different kind be presented, they may be attracted and retained by the central particle notwithstanding, provided its attraction to these last
P be stronger than to the former: and accordingly, as these last are more weakly or strongly attracted, they will either form an additional stratum without, or will be urged inwards, so as to displace the others by forcing them out of the sphere of
Q attraction. The phenomena will likewise be different in consequence of the greater or less force of attraction mutually exerted between the particles of different kinds applied to the central particle.

R A particle surrounded by as many of another kind as it can retain, may be considered as a simple particle with respect to such particles of a third kind, as it can attract and retain without displacing the former.

S Let a particle be supposed to be surrounded by as many of another kind as it can retain, and also by particles of a third kind, enveloping the former; let the attraction of the central particle be supposed greater in like circumstances with respect to the external kind, than to the kind of particles which are nearest to it, but stronger on these last, merely on account of their proximity; then, if the whole be heated, the respective distances of all the particles will be increased (113, x); this increase may augment the distances of the nearer in a higher proportion than of the remote particles, and consequently cause the attractions of the central particle

particle on each to approach nearer to equality, or even cause attraction on the external stratum to become greatest; and again, the inner stratum of particles having their interstices rendered larger, may admit the outer to pass through without impediment, and possess the nearer place: that is to say, heat may cause changes of combination to take place that would not have obtained at a lower temperature. T

The simplest parts that enter into the composition of bodies, namely, such parts as have not hitherto been decomposed by any method of analysis, or obtained by the combination of other simple bodies, are termed elements or first principles. U

When a combination of two first principles enters into the composition of a body, by uniting with some other principle or principles, this combination is termed a secondary principle of the body it enters into (140, R). V

Thus, when soap is dissolved in ardent spirit a combination is formed into which the soap though not a simple substance, enters as a secondary principle, and from which it may be again separated, by proper methods, in its original form.

When principles are combined in such proportions as to form a compound that exhibits the least possible any of the distinguishing properties of the principles, they are said to be saturated with each other. If either principle exceed this proportion, it is said to be imperfectly or partially saturated, and the other is said to be supersaturated. W

For

For example, if ſpirit of ſalt, or the marine acid, be added to ſalt of ſoda, or the marine alkali; the compound will exhibit acid properties, if the firſt abound beyond a certain proportion; or if the latter predominate, the alkaline properties will prevail; but if each be in due quantity, the compound will be common culinary ſalt, neither acid nor alkaline.

x Mixture is the union of principles, which remain nevertheleſs in conſiderable maſſes that adhere to each other reſpectively, either by reaſon of the ſimilar principles having a greater attraction to each other than to the principles of another kind, or becauſe the heat of the maſs is not ſufficiently great (141, T) to cauſe that change which would produce an intimate combination of the whole.

Oil and water, when ſhaken together, do not combine but only mix, becauſe the parts of each reſpectively attract thoſe of the ſame kind more ſtrongly than the other: ſo likewiſe pot-aſh and ſand may be mixed without combining, but an increaſe of temperature in the furnace of a glaſs-houſe will cauſe them to unite, and form the combination called glaſs.

Y To produce a change in the combination of the parts of bodies, it is in general required that the temperature of the whole ſhould be ſufficiently high to melt at leaſt one of the principles.

Z When a fluid combines with another body without loſing its fluidity, this laſt is ſaid to be held in

in ſolution, or diſſolved, and the fluid is called a ſolvent or menſtruum.

A menſtruum ſaturated with one principle may, A
notwithſtanding, take up another (139, N, O).

Thus ſalt may be diſſolved in water, and when it is ſaturated, and will not act on ſalt, it will diſſolve ſugar.

When a fluid that holds one or more principles B
in ſolution lets one fall upon the addition of ſome new principle to which the combination has a greater affinity, the principle let fall is ſaid to be precipitated by the newly added principle, which is called the precipitant.

Epſom ſalt conſiſts of magneſia, combined with the marine acid. If this ſalt be diſſolved in water, and ſalt of tartar be added, the magneſia will fall to the bottom in the form of a white powder; and the ſalt of tartar will combine with the acid.

When two principles being united are ſo ſepa- C
rated on the addition of a third, that one of the original principles quits the other, and forms a new combination with the third, the decompoſition and new combination are ſaid to be produced by ſimple affinity.

Common ſalt, as has been already obſerved, is a combination of the marine acid with the marine alkali. If oil of vitriol, or the vitriolic acid be added, the alkali will quit its acid to unite by ſtronger affinity with the acid laſt added: with which it will form a new ſalt, called Glauber's ſalt,

ſalt, while the marine acid being diſengaged, flies off in an elaſtic form.

D When two compounds, conſiſting each of two principles, are preſented to each other, and the combinations change the order of their principles, becauſe the attractions of one principle of the one to one principle of the other, and of the remaining principle of the one to the remaining principle of the other, are, together, ſtronger than the attractions that tend to preſerve the original form, the two decompoſitions, and two new combinations, are ſaid to be produced by double affinity.

Sal-ammoniac is compoſed of the marine acid, combined with the volatile alkali, or ſalt commonly uſed in ſmelling bottles. If ſal-ammoniac in powder be mixed with ſlaked lime, the marine acid unites with the lime, and the water of the lime joins with the volatile alkali, which riſes immediately in penetrating fumes. This mixture being haſtily put into a retort, the water and volatile alkali come over together, by the aſſiſtance of a gentle heat, in the form of a pungent fluid, called the cauſtic volatile alkali, or, by apothecaries, ſpirit of ſal-ammoniac with quicklime. In this proceſs it is not ſimply the attraction of the marine acid to the quicklime, nor the attraction of the water to the alkali that occaſions the double change of combination, but it is the united force of both attractions: for if dry hot quicklime, that is to ſay, quicklime containing no water, be made uſe of, the ſal-ammoniac

ammoniac is not decomposed, the simple attraction of the marine acid to the quicklime not being sufficient to overcome the attraction of its component principles.

There are many [illegible] compounded effects of the mutual attraction [illegible] parts of bodies [illegible] circumstances [illegible] for it requires [illegible] experiments with facts, a li[illegible] habits of reasoning, and [illegible] direction.

Fluids in general [illegible] of any substance when [illegible] but this is not universal [illegible] general fact seems to be, that [illegible] solution may be better [illegible] at a higher temperature; that in partial solution, where all the principles are not taken up, the heat, by volatilizing some principles, may render the solution of the residue more easy; and the reason why in some cases less is taken up by a fluid at a higher than at a lower temperature is, probably, that the general effect of heat being to oppose (213. x) the attractions between bodies may operate more strongly than the other causes here taken notice of. But it is probable that none of the cases wherein this effect seems to take place are of a simple nature.

Chemical processes, in which water is a principal agent, are said to be performed in the moist way: those which are performed at high temperatures, and wherein water is little, if at all, concerned, are said to be performed in the dry way.

CHAP. IV.

OF THE FIRST COMPONENT PRINCIPLES OF BODIES, OR SUCH AS ARE THE MOST SIMPLE.

All bodies are parts, either of animal, vegetable, or mineral ſubſtances. During the life of animal and vegetable ſubſtances, various proceſſes, both mechanical and chemical, are carried on within them, by means hitherto very imperfectly explained. The principles that enter into the compoſition of theſe are far from being ſimple. As ſoon as their ſtructure is, by violence or otherwiſe, ſo impaired as to deſtroy life, the arrangement of chemical principles begins to change. Decompoſitions and new combinations take place among the ſolid as well as the fluid parts. The organization of the veſſels is deſtroyed, and after a certain time the whole, as far as obſervation can follow the proceſſes, returns to the general repoſitory of minerals or unorganized matter, from which it originated, and cannot again be diſtinguiſhed.

The ſimpleſt bodies are air, water, ſalts, earths, and inflammables. Many chemical philoſophers of the firſt eminence are now buſied in diſcovering or aſcertaining the component parts of theſe, but the limits of the preſent work, as well as its intention, will not admit of entering, except occaſionally,

fionally, into the confideration either of the facts or theories they have exhibited to the world.

Many fubftances may affume the aerial form, K either from their difengagement by ftronger affinity (143, c), or by increafing their temperature. Air is diftinguifhed from tranfparent vapor by its more permanent elafticity. It is probable that this difference confifts in the greater aptitude of vapor for imparting its heat to other bodies, or combining with them. There are feveral kinds of air that lofe their elafticity and combine with water, if prefented to them; and there are others that cannot be kept in an elaftic form for any length of time, merely becaufe of their aptitude to combine with every fluid that has hitherto been ufed to confine them.

When air is claffed among fimple fubftances, no- L thing more is therefore to be underftood than that a variety of principles are obtainable in this form, much more fimple than it is probable they will ever be met with in any other.

Water enters as a fimple fubftance into the M compofition of many bodies. There are no abfolutely unequivocal proofs of its having been changed or decompofed in any chemical procefs. Yet if N inflammable air and pure air be burned together, water is produced which is faid to be equal in weight to the quantities of air made ufe of. Whence it is concluded, that water is compofed of thofe airs combined together in the heat of combuftion (141, T), during which act, the latent heat

(118, v. 124, w) that maintained the aerial form is given out.

o The pureſt natural water is rain, collected at a diſtance from trees or buildings. For chemical purpoſes, water ſhould be diſtilled in glaſs veſſels, with a heat not ſufficient to make it boil, and no more than two-thirds of the whole quantity ſhould be drawn off. The lighteſt, cleareſt, and moſt taſteleſs water, which lathers well with ſoap, is purer than ſuch waters as are deficient in theſe qualities.

p Salts are ſuch bodies as are diſſolvable for the moſt part in leſs than two hundred times their weight of boiling water, and more or leſs affect the organ of taſte. They liquefy by heat, which cauſes them to evaporate, either in part or totally, according to the component parts of the ſalt, and the intenſity of temperature.

q Simple ſalts are either acids or alkalis. Compound ſalts are either combinations of acids with alkalis, which are called neutral ſalts; of acids with earth, called middle ſalts; of acids with metals, called metallic ſalts; or combinations of theſe with each other.

r Earths are taſteleſs brittle ſubſtances, differing from ſalts by their leſs ſolubility in water, the diſtinguiſhing limit being not founded in nature, but arbitrary. Water at a high temperature, as when confined in the ſtrong metallic veſſel called Papin's Digeſter, will diſſolve ſome, and probably all earths. The ſubſtances claſſed under this

title are not soluble in the open air in less than between six and seven hundred times their weight of boiling water. They are not susceptible of the metallic lustre. In the fire they are fixed. A low heat does not alter their form or other properties, and simple earths are not fusible alone, by the most violent heat that art can produce.

The well known simple earths are five; calcareous earth, or pure quick-lime; ponderous earth; magnesia; argillaceous earth, or pure clay; and siliceous earth. These earths have never yet been decomposed. Like all other simple substances, they are never found pure, but the methods used in chemistry can easily separate them from the matters they may happen to be either combined or mixed with.

Late experiments have ascertained the existence of several other Earths; which however are neither so plentifully diffused, nor hitherto so well known as to require a place in this Elementary Treatise, except by mere enumeration. These are, the Earth of Adamantine Spar*; the Earth from the Jargon of Ceylon†, both discovered by Klaproth; the fusible Earth from New South Wales, discovered by Wedgwood‡; and the Earth from the Spar called the Strontionite, discovered by Dr. Crawford§. For their distinctive characters and

* Annales de Chimie, I. 183.

† Journal de Phisique, for March 1790

‡ Philosophical Transactions for 1790. p 306.

§ Medical Communications, Vol. II. also Phil. Trans. 1784.

properties, the reader muſt recur to the authorities quoted below.

Every change produced in bodies is evidently the conſequence of motions among their parts. When theſe motions are diſtinguiſhable by the ſenſes, the effects are called mechanical; in moſt other caſes they claſs with chemical proceſſes. One of the moſt ſtriking and obvious means of producing the latter change in bodies, conſiſts in altering their temperature. The means of doing this has been explained in the chapter upon heat. Whenever the temperature of bodies is raiſed ſo as to render them luminous, a remarkable difference is ſeen in their habitudes when left to themſelves. Some of theſe ignited bodies gradually become cooled down to the temperature of the ſurrounding air, without having undergone any notable change. Others, on the contrary, provided reſpirable air be preſent, not only retain their luminous ſtate and temperature, but become hotter, are internally agitated as to their parts, and do not return to the common temperature until a complicated chemical proceſs has been effected to the entire deſtruction of the original form and moſt of the properties of the body itſelf. This proceſs is diſtinguiſhed by the name of combuſtion, and the body thus changed is ſaid to have been burned. It is evident that all bodies whatever may be claſſed either as combuſtible or incombuſtible; and it is equally clear that the doctrine of combuſtion muſt conſtitute a large part of chemical ſcience.

Whenever we discern an eminent property in any substance submitted to our observation, we either commit the fact to memory, to be applied in our future reasonings, or else we deduce its existence from some former fact supposed to have been established in the same manner. Thus in the instance before us, philosophers, after collecting as much information respecting combustion as they could, were formerly content to rank combustibility among the properties of a few bodies, such as oils, sulphurs, and bitumens; and accounted for the combustibility of other matters by supposing them to contain more or less of these ingredients. This doctrine was rendered more general by the celebrated chemists Becher and Stahl, and their numerous followers. Their theory is well known by the name of the Doctrine of Phlogiston. According to the most modern arrangement of this theory, a body or chemical principle eminently or rather solely combustible, always identical, capable of passing from one combination to another, but never yet exhibited in a distinct state, is the cause of combustibility in all bodies which contain it. It has been ascertained by our cotemporaries that combustion does not take place but when respirable air is present, and that this air is absorbed and enters into combination with the body during its combustion. The phlogistian philosophers have been compelled by this fact to modify their theory, and to affirm either that the phlogiston itself unites with the air, and forms a compound which, according to cir-

 cumstances,

cumstances, unites with the residue or flies off, or else that the air itself unites with the residual matter, while the phlogiston escapes. The increase of temperature which takes place during combustion, is in every theory accounted for from the consideration of the changes of capacity that take place during the process, and more especially it is ascertained from experiment and inference that the air in condensation gives out a large quantity of heat.

A respectable number of modern chemists have altogether rejected this modification of the ancient doctrine of sulphurs and oils. As it is evidently no advance in theory to say a body is combustible because it contains sulphur or phlogiston, which are also said to be combustible, it will follow that our enquiries ought to be directed to the events which take place with these last bodies, or at least with such as can be unequivocally submitted to observation. In all such clear and unexceptionable cases the facts are simply, that the combustible body and respirable air are brought into contact; that the temperature of the body is raised by communication or by other means; that at the requisite elevation of temperature the respirable air begins to unite with the body itself, at the same time that heat and light are developed; that this process goes on until the whole of the respirable air is absorbed, or until the body is saturated with that principle; and that the new product is in all cases which admit of weight or mensuration equal to the weight of the air which has disappeared, added to that of the body

body which was subjected to combustion. The experiments from which these facts are deduced are the combustion of phosphorus with vital air in a closed vessel, and the calcination or combustion of mercury and other metallic bodies, for which the writings of Lavoisier and the notes of the academicians upon Kirwan's phlogiston, may be consulted. The preceding circumstances do not appear to teach us any thing further than that respirable air and a combustible body have united, and that light and heat have appeared. Rejecting therefore at present the consideration of the light and heat, which, if they be distinct substances, can scarcely be classed among principles of density sufficient to be weighed or measured, it may be inferred that combustion consists in, or at least follows, whenever there is a rapid union of vital air with any other body. This is the pneumatic or antiphlogiston doctrine, which though not firmly established in all its parts, yet being much more simply and distinctly deduced from direct observation than the doctrine of Stahl, is likely to be universally received as soon as the habits of philosophizing according to the old theory shall have been eradicated.

The simplest inflammable substances are, inflammable air, diamond, plumbago, sulphurs, and metals. More compounded inflammable matter are, hepatic air, spirits, ether, oils, bitumens, coal, and generally all animal and vegetable substances in their natural state.

When

w When a metal is ſubjected to combuſtion or any other equivalent proceſs, it loſes its malleability, aſſumes many of the properties of an earth, and no longer exhibits the luſtre peculiar to this claſs of bodies. In this ſtate it is called a calx, and forms combinations with ſaline ſubſtances. When the metallic ſtate is reſtored to a metallic calx, the metal is ſaid to be revived.

Every ſubſtance, which paſſes from a fluid to a ſolid ſtate, appears to have its parts arranged in a ſymmetrical order, that extends to a greater or leſs number of particles, accordingly as the influence of external circumſtances, or the rapidity with which the change of ſtate is performed are concerned in the proceſs. Thus we ſee that moſt minerals; ſaline combinations, whether obtained by ſolution or ſublimation; and metals, if ſuffered to cool ſlowly, have their peculiar forms, though in ſome more evident and diſtinguiſhable than in others. This property, called cryſtallization, is by ſome diſtinguiſhed into two kinds: the one made in a menſtruum, as ſalt cryſtallizes in water, and the other by mere cooling, as when water freezes alone. Thoſe who affirm that heat is matter, imagine it to be the medium in which this laſt cryſtallization is performed.

It would be of ſingular advantage in mineralogy, v and every other ſcience related to chemiſtry, if the external appearance and figure of bodies could be applied to the purpoſe of knowing what claſs they belong to. This is indeed done with ſome

ſucceſs,

ſucceſs, by ſuch as have opportunities of examining many ſpecimens; but no conciſe general rules have yet been eſtabliſhed, on account of the exceedingly great number of exceptions that ariſe from circumſtances, or differences in the compound, either too minute for the chemical analyſis to aſcertain, or apparently too inſignificant to excite the attention of the obſerver.

CHAP. V.

THE METHOD OF MAKING EXPERIMENTS ON VARIOUS KINDS OF AIR.

Experiments to be made with the various kinds of air require an apparatus of veſſels proper for confining it. The chief are thoſe we are about to deſcribe.

Fig. 157, A, is a tub for containing water. In this tub is fixed a ſhelf K, K, ſo placed that it may be about an inch below the ſurface of the water, when the tub is nearly full. B and F are cylindrical glaſs jars. C is a bottle, into the neck of which the bent tube D is fitted, by grinding. Suppoſe now that the veſſel B be plunged in the water, ſo as to be filled, and afterwards raiſed, with its mouth downwards, and placed on the ſhelf K, it will continue full of water on the principle of the barometer: if its rim be made to overhang the edge of the ſhelf, it will be eaſy to introduce

troduce the end of the tube D beneath it; and if the vessel C contain such matters as by their action on each other furnish air; the air will pass through the tube D, and rise to the top of B, expelling more or less of the water. A candle may be applied beneath C in cases where heat is wanted.

X E is a small retort, supposed to contain materials that afford air to the vessel F.

Y Air may be transferred from one vessel to another by the help of a glass-funnel under water. Thus the vessel G being supposed to be previously filled with water, and placed on the shelf, over a hole in which the funnel H is stuck, the air may be poured out of the vessel I through the funnel into G.

Z Many kinds of air combine with water, and therefore require to be treated in an apparatus in which quicksilver is made use of. This fluid being very ponderous, and of considerable price; motives both of convenience and œconomy, require that the apparatus should be made smaller than when water is used.

A Where the change of dimensions that follows from the mixture of different kinds of air is required to be ascertained, a graduated tube (fig. 158) is made use of. And because the salubrity of common air is supposed to be determinable by this means, such a tube is called an eudiometer tube. There are apparatus of a less simple construction, which are intended to answer the same purpose, and are called eudiometers.

Fig.

Fig. 159 is a glaſs-apparatus for impregnating water with fixed air. It conſiſts of three veſſels. The lower veſſel C has an orifice or neck D, with a ground-ſtopper; the veſſel B is fitted by grinding, into the neck H of the veſſel D. At E is a glaſs-cock; and in the lower neck of the middle veſſel B is a valve, opening upwards. This valve is compoſed of two tubes of glaſs, with a moveable plano-convex lens between, as repreſented in fig. 160. The upper veſſel A is fitted, by grinding, into the neck I of the veſſel B. It terminates below, in a tubular form G, and is cloſed at top by the ſtopper F. The proceſs is thus conducted. Pieces either of marble or chalk are put into the lower veſſel C, and water poured thereon; the veſſel B is then filled with water, and placed on C, by inſerting its lower part in the neck H. The empty veſſel A is placed in like manner on B, its ſtopper F being in its place. Laſtly, a ſmall quantity of oil of vitriol is poured into the orifice D, which is then cloſed. The vitriolic acid combines with the earthy part of the marble or chalk, and diſengages the fixed air that entered into its combination, which, of courſe, paſſes through the valve at H, to the upper part of the veſſel B. The diſplaced water being prevented from deſcending by the valve, is forced up through the tube G into the veſſel A; at the ſame time that the common air in this laſt veſſel is partly condenſed, and partly eſcapes, by lifting the ſtopper F, which is ground conical, to prevent its ſticking. When the water in B has deſcended as low as the orifice of G, the fixed air paſſes

up

up through the tube instead of water, and expels the common air from the upper part of A. Both surfaces of the water being thus exposed to the fixed air, this fluid gradually absorbed, gives the water that lively subacid taste, which is the distinguishing character of the Pyrmont water.

D Those who are not provided with the apparatus here described, may supply its place by the help of utensils that are every where to be met with. A (fig. 161) is a half-pint phial; B a bladder, whose neck is tied round a cork that fits the mouth of A, and has a hole made through it with a heated wire. The same bladder is seen at D, with a bent tube E stuck in the hole of the cork. In the phial A is chalk, with water acidulated with oil of vitriol. The fixed air that rises is received in the bladder, previously moistened. While the bladder is filling, a quart bottle C, full of water, is to be inverted into the bason F, which likewise containing a little water, prevents the common air from rising into C. As soon as the bladder is filled it is taken from the phial A. The tube E is inserted, and its orifice carefully placed under the mouth of the quart bottle C, as in the figure. The bladder being then pressed, the fixed air ascends to the upper part of C at the same time that an equal bulk of water descends into the bason. By agitating the bottle C, without withdrawing its neck from the water, the fixed air becomes absorbed in a few seconds, and the water reascends. This process being repeated two or three

times,

times, the water becomes saturated, as appears by the fixed air being no longer absorbed.

Though this method possesses the advantage of E
convenience, to such as cannot use the other, yet it does not produce so strong an impregnation; partly, because the water takes up more fixed air when condensed by pressure, and partly, because in this last method the water in the bason being exposed to the atmosphere, gives out a portion of the fixed air it contains.

CHAP. VI.

CONCERNING WATER, ACIDS, AND ALKALIS.

The properties of water have been so often ad- F
verted to in the former parts of this Treatise, that it is the less necessary to treat them diffusively in this place. Water in freezing usually assumes a symmetrical form, which is that of needles crossing each other at angles of 60° or 120°. This arrangement of the parts occasions the mass to occupy considerably more space than before, and the expansion, which is performed almost instantly, is effected with such prodigious force, that no vessel has yet been used that can withstand it. Bomb-shells and gun-barrels have been broken by freezing water in them.

From this expansion it is, that ice is specifically G

lefs heavy than water, and confequently floats upon its furface.

It is equally difficult to afcertain any limits to the force with which water in a ftate of vapour may be expanded by heat.

I Water is fo univerfal a folvent, and enters into fo many chemical proceffes, that moft philofophers overlook its agency, in the confideration of facts it is concerned in: and to this circumftance it is, perhaps, chiefly owing, that its component parts have hitherto been undifcovered.

K Acids are falts, which are four to the tafte. They convert the blue colour of tincture of heliotropium * to a red, and caufe an ebullition or efcape of air, if applied to chalk or mild alkalis. The affinity of the purer acids for water is fuch, that for the moft part they cannot be obtained in a concrete ftate; and their action on other fubftances is fo general, that they are never found pure, but require the affiftance of art to render them fo.

L The acids found in the mineral kingdom are, the aerial acid or fixed air; the vitriolic acid, known in commerce by the name of oil of vitriol; the nitrous acid, called fpirit of nitre; the marine acid, called fpirit of falt; the acid of fpar, or fparry acid; the acid of borax, called fedative falt; the fuccinous acid, or acid of amber; the phofphoric acid; the acid of molybdena; the acid of arfenic, and the acid of tungften or wolfram.

* Called litmus by the dyers.

The

The vegetable kingdom affords many acids: those which have been examined chemically are vinegar, the acids of tartar, of ſugar, of ſorrel, of lemons, and of benjamin. M

The acids peculiar to the animal kingdom are the acids of milk, of ſugar of milk, of ants, of tallow and of pruſſian blue. N

Vegetable and animal acids are ſo far from being ſimple, that many of them are reſolvable into air by the proceſs of diſtillation. The aerial and the phoſphoric acids, though enumerated in the mineral kingdom, are alſo obtained in great quantities, both from animal and vegetable matters. O

Modern chemiſtry has diſcovered many acids, and there is good reaſon to expect that their component parts will be diſcloſed by the labours of our cotemporaries; but the alkaline ſalts ſtill remain no more than three in number, and have not hitherto been treated in any method that promiſes a ſatisfactory analyſis. They have a peculiar cauſtic urinous taſte, and convert the blue colour of the tincture of heliotropium to a green. P

The vegetable fixed alkali, impure ſamples of which are met with in commerce, under the names of ſalt of tartar, pot-aſh, pearl-aſh, &c. is moſt plentifully obtained from vegetable ſubſtances. Q

The mineral fixed alkali is met with in an impure ſtate, in commerce, under the names of kelp, barilla, ſoda, or ſalt of ſoda. It is found in the earth, either pure or in combination with other matters. The ſea contains immenſe quantities of R

it, where it is one of the conſtituent parts of common ſalt, and it is the moſt profitably obtained from vegetables that contain ſea-ſalt.

s The volatile alkali is ſold by the apothecaries under the name of ſmelling ſalts, or ſal-volatile, in which ſtate it is combined with a large portion of aerial acid. It is moſt plentifully obtained from animal ſubſtances, being combined in them with other principles. The proceſs of putrefaction throws it off into the air, together with other volatile matters that vitiate, and often diſguiſe its ſmell.

T Alkalis, combined with the aerial acid, are ſaid to be mild; when they are diveſted of every acid they are called cauſtic.

CHAP. VII.

THE PROPERTIES OF SIMPLE OR PRIMITIVE EARTHS.

CALCAREOUS earth exiſts in a conſiderably pure ſtate in common quicklime. If pounded chalk be ſeveral times boiled in diſtilled water to ſeparate by ſolution ſuch marine matters as may be found in it, the remainder will conſiſt almoſt entirely of calcareous earth, united to about an equal weight of fixed air, or aerial acid. If diſtilled vinegar be added to this powder, it will form a ſaline combination with the earth only, at the ſame time that the fixed air, aſſuming an elaſtic form, flies off. To this ſolution, decanted from the impurities, mild volatile alkali being added, the alkali will unite with the vinegar, while the calcareous earth combines with the fixed air of the alkali, and falls to the bottom. This powder, well waſhed and dried, is pure chalk, or calcareous earth united with fixed air. This laſt may be driven off by fire, and will leave the pure calcareous earth diſengaged.

Calcareous earth requires about ſix hundred and eighty times its weight of water to diſſolve it at the temperature of 60°, to which it gives a pungent taſte. This water, called lime-water, acquires a white cruſt on the ſurface, by expoſure to the atmoſphere, which breaks and falls to the bottom, another cruſt forming ſoon after, and ſo on till the

whole of the lime is precipitated. The precipitate is chalk, or mild calcareous earth; whence the process may be easily explained. For chalk is scarcely, if at all, soluble in water: and the lime contained in the water being converted into chalk, by the accession of fixed air from the atmosphere, becomes an insoluble crust, that falls at intervals, as its quantity becomes too great to be supported at the surface.

A This earth is soluble in all acids. It is infusible in every degree of heat yet obtained, except that of the famous lens of PARKER, in London, which produced a slight beginning of fusion. Yet it will melt in a more moderate heat, if mixed with other earths, of which it then appears to be the flux or solvent.

B The specimens of calcareous earth are very many. Lime-stone, chalk, many kinds of marble, and almost every one of the numerous varieties of spars, whether transparent or opake, consist of this earth combined either with the aerial or some other acid. Aerated calcareous earth may be known to predominate in any mineral, when it froths on the application of an acid.

C Terra ponderosa, or ponderous earth, is not met with in abundance. The commonest specimens are the ponderous spar, or marmor metallicum, so called from its great weight, best known to our English miners by the name of cawk. It is met with opake, white, grey or yellowish, either irregularly shaped, or in a singular form, resem-

bling

bling convex lenſes, ſet edgewiſe into the maſs it adheres to. The tranſparent ſpecimens are priſmical, and of conſiderable hardneſs. All theſe conſiſt of ponderous earth, combined with the vitriolic acid.

Ponderous earth, combined with the aerial acid, D
has been found in Lancaſhire, and elſewhere. It reſembles alum, but is of a ſtriated texture, and its ſpecific gravity is 4,331.

If the ponderous ſpar, or ponderous earth com- E
bined with the vitriolic acid, be expoſed to a ſtrong red heat, for about two hours, with near twice its weight of fixed alkali, the acid quits the earth to combine with this laſt, forming a neutral ſalt, which may be waſhed away, and leaves the earth combined with fixed air and water. The fixed air may be expelled by heat.

Pure ponderous earth, thus obtained, is ſoluble F
in about nine hundred times its weight of water. This water reſembles lime-water in taſte, and depoſits its earth, by expoſure to the air, in the ſame manner.

The properties of ponderous and calcareous G
earth agree in many reſpects; but in others they differ ſo much, as clearly to ſhew that they are not one and the ſame earth, as has been ſuſpected*.

* See Bergman's Works, Kirwan's Mineralogy, and Withering on the terra ponderoſa aerata, in Phil. Tranſ. for 1784.

H Magnesia,* or magnesian earth, enters into the composition of some earthy substances, the chief of which are steatites, soap-rock, French chalk, asbestos, and talk. It is in the sea-water in great quantities, combined either with the marine or vitriolic acids. Epsom salt is a combination of the vitriolic acid with magnesia. If this be dissolved in water, and mild volatile alkali added, the magnesia is precipitated in combination with the fixed air, while the alkali unites with the vitriolic acid. The magnesia thus obtained, contains one fourth of its weight in fixed air, and about the same quantity of water. Both are driven off by fire, by which the magnesia is rendered pure, and has somewhat less than half the weight it possessed in its former mild state.

I Clay or argillaceous earth, is found every where in great quantities, but in the native specimens it is always mixed with a considerable quantity of other earths. Alum is a salt, consisting of argillaceous earth, combined with the vitriolic acid. If it be dissolved in water, and the mild volatile alkali added, this last unites with the acid while the earth is precipitated, combined with a small proportion of the aerial acid.

K Argillaceous earth imbibes water strongly, but is scarcely soluble therein. When sufficiently divided, it forms a tenacious mass with water, so as to admit of being moulded into various forms. It contracts very much by heat, and acquires a flinty

flinty hardneſs by baking, which does not then ſuffer any alteration from water; though its original ſoftneſs and tenacity may be again reſtored by ſolution in acids, and precipitation.

This earth, which is ſo uſeful in the arts, has been applied*, with great ſucceſs to the admeaſurement of the higher degrees of heat. For as the expanſion of the mercury, in a common thermometer, indicates the ſucceſſive augmentations of temperature, ſo the contractions of the volume of a ſmall brick of clay, by expoſure to ignition, are found to be greater, the more violent the heat. By the help of which property we are in poſſeſſion of an invaluable method of meaſuring and comparing thoſe high temperatures. L

Siliceous earth, which is alſo called cryſtalline, or vitrifiable earth, abounds in many ſubſtances. Cryſtal is one of the pureſt ſpecimens. Extreme hardneſs is moſt commonly a characteriſtic of ſiliceous earths, ſo that ſtones, in which it predominates, will ſtrike fire with ſteel, or at leaſt will ſcratch its ſurface, however highly tempered. M

To procure ſiliceous earth in a pure ſtate, clear cryſtals, or quartz, muſt be reduced into powder, and melted with four times its weight of fixed alkali. The compound is then to be diſſolved in water, and the vitriolic acid added in conſiderable quantity. The alkali and acid unite together, forming a ſalt that remains in ſolution: if N

* By J. Wedgewood, Eſq. See the Phil. Tranſ.

there be any other kind of earth preſent, it will likewiſe combine with the ſuperfluous acid. But the ſiliceous earth being diſengaged, falls to the bottom in a ſubtile powder, which muſt be cleared of the ſaline liquor by decantation, and repeated waſhing with pure water.

o This earth is acted on by no acid but the acid of ſpar, or fluor. Fixed alkalis diſſolve it, either in the dry or moiſt way. Like the other earths, it is not fuſible without addition by any heat yet obtained.

p Though the ſimple earths are all infuſible alone, yet they may be fuſed by mixture with each other. The calcareous earth is found to act as a menſtruum in diſſolving other earths by fuſion; and when it has once acted on any earth, a compound menſtruum is formed, which is ſtill more efficacious on other earths. Hence it is that equal parts of any three of the ſimple earths may be fuſed into glaſs, provided calcareous earth be one of the number.

CHAP.

CHAP. VIII.

THE GENERAL PROPERTIES OF COMBUSTIBLE BODIES.

Combustibility was formerly ſuppoſed to conſtitute a diſtinct and eſſential character of bodies; and it ſtill continues to poſſeſs ſufficient importance with regard to the great and obvious changes in the univerſe to be admitted as a criterion of arrangement. All bodies are either combuſtible or incombuſtible, but it is highly probable that this difference ariſes merely from the latter having undergone the proceſs of combuſtion or combination with vital air. Whether this general notion be admitted or not is however of leſs conſequence in our deductions from exiſting and known facts. The bodies which are capable of undergoing combuſtion are not numerous. Moſt of them are acidifiable, and perhaps they might all prove ſo if we could acquire the means of completely burning them.

If we overlook the theory of Phlogiſton for want of ſufficient proof of its validity, we ſhall be neceſſarily led to conſider thoſe combuſtible ſubſtances as ſimple, which we have not hitherto been able to decompoſe after they have been burned by any reduction capable of ſhewing that they are convertible into ſubſtances different from the original

ginal body, and the vital air employed in burning it. But we muſt not at the ſame time overlook the circumſtance, that in many inſtances reſpecting theſe fundamental enquiries, much of reaſoning and no ſmall quantity of incomplete deduction neceſſarily mixes itſelf in the attempts which philoſophers make merely to aſcertain the bare matter of fact, in experiments where weight and meaſure can ſcarcely be applied, and in moſt inſtances certainly cannot. Under theſe limitations which the cautious and unbiaſſed ſpirit which ought to prevail in our reſearches neceſſarily dictates, we proceed to enumerate the following as ſimple combuſtible ſubſtances.

Light inflammable air, called Hydrogen by the Anti-Phlogiſtians, is an inflammable ſubſtance which has never been exhibited alone but in the ſtate of permanent elaſticity. In this ſtate it is much lighter than the air of the atmoſphere. It is affirmed that the pureſt kind is ſeventeen times as light. Whether it produces any acid by combuſtion has not been incontrovertably aſcertained; but there is little doubt that in a certain proportion it forms more water by combuſtion with pure vital air. Beſides the inflammable air which is light, there are other kinds generally much more heavy and burning with a leſs luminous flame. From well inſtituted experiments it appears to be proved that theſe laſt fluids conſiſt of the light inflammable air holding ſome other combuſtible matters in ſolution, ſuch as ſulphur, phoſphorus, coaly

coaly matter, arſenic, and oil. The ſulphureous ſolution is diſtinguiſhed by the name of Hepatic air, becauſe uſually obtained from the combination of alkali and ſulphur called Hepar. The phoſphorated inflammable air, is called phoſphoric air.

The diamond is a combuſtible ſubſtance which, on account of its great commercial value, has not been ſubmitted to many experiments; it is formed in various parts of the Mogul empire, and alſo in the Eaſt Indian Iſlands, and the Brazils. It is uſually of an octohedral form, though not unfrequently in round maſſes. The conſent of mankind has ſtamped a prodigious value on the diamond; its great luſtre, which ſeems to have been the property that originally attracted their notice, is owing to two cauſes. The firſt is, that being the hardeſt of all bodies, it takes and preſerves a moſt exquiſite poliſh, and the other is, that its refractive power is ſo much greater than that of any other medium, as to occaſion all the light to be reflected (1, 270. A) which falls on any of its hinder ſurfaces at a greater angle of incidence than 24¼ degrees. Now at a leſs angle of incidence in glaſs on the internal ſurface than 41 degrees, the light will be tranſmitted; conſequently if an artificial gem and a real diamond be compared, the light falling on each alike ſituated will be thrown back with its full glare from a diamond not only in all the caſes wherein glaſs will reflect it, but likewiſe at all the angles between

41° and $24\frac{1}{4}$°, while the glaſs ſuffering it to paſs through will appear lifeleſs and dull. It is no wonder, therefore, that the effect of the diamond is ſo much greater.

No acid but the vitriolic has any effect on this gem, in which if Diamond powder be triturated, and evaporation carried on nearly to dryneſs, the acid grows black, and depoſits pellicles that burn and are almoſt entirely conſumed.

In a heat ſomewhat greater than is required to melt ſilver, diamond is entirely volatilized and conſumed, producing a ſlight flame and leaving a ſoot behind. Neither the elaſtic nor fixed reſidues have been examined.

Sulphur or brimſtone is an inflammable ſubſtance of a light yellow colour, either tranſparent or opake, brittle, odorant; it enters into combination with oils, alkalis, earths, and metals, at a temperature not much greater than that of boiling water; it evaporates in the open air, and is decompoſed, at the ſame time emitting a flame which by day has the appearance of a white fume, but in the dark is luminous, though its heat is ſo ſmall that it may be ſuffered to play againſt the palm of the hand without much inconvenience. At a higher temperature it burns with a vivid blue flame, and is decompoſed more rapidly, the acid taking the form of air of a moſt ſuffocating odour. This air called vitriolic acid air, unites with water if preſent, and forms the volatile vitriolic acid.

Sulphur

Sulphur is not decompoſed, but ſublimes without alteration if heated in a cloſe veſſel.

Phoſphorus is a yellow or white tranſparent ſubſtance conſiderably reſembling ſulphur in its properties. Like ſulphur it burns with two kinds of flame, but is much more inflammable. Fourcroy affirms that the ſlow temperature with a white luminous fume or flame, takes place in every temperature with which we are acquainted; and that the rapid combuſtion commences at 147°. I found that the phoſphorus of urine prepared by Godfrey, which was probably leſs pure than that mentioned by Fourcroy, was not luminous in a freezing atmoſphere at about 14°, but became luminous repeatedly as often as it was brought into a room at the temperature of 60°, and that the ſame phoſphorus, placed in a veſſel of water, burſt into the rapid and ſtrongly luminous combuſtion as ſoon as the water had acquired 160° of heat. In cloſe veſſels phoſphorus ſublimes entire by heat, provided reſpirable air be not preſent. The phoſphoric acid is the product of the combuſtion of this ſubſtance. Phoſphorus unites with ſulphur, and with metals; is ſoluble in inflammable air, in oils, and in ardent ſpirit; combines with alkalis, and ſeparates ſeveral of the metals from acids by reduction, at the ſame time that itſelf becomes acidified. Phoſphorus, like ſulphur, is found abundantly in the mineral kingdom. The greateſt quantities are combined with calcareous earths.

Coaly matter, which is obtained moſt abundantly from vegetable ſubſtances by igniting them in ſuch a ſituation as to prevent the acceſs of air, at the ſame time that the volatile parts are at liberty to fly off, is conſidered as a ſimple ſubſtance, and has been diſtinguiſhed by the name of Carbone. Charcoal contains a ſmall proportion of ſaline matter and earth, but the combuſtible part takes fire when conſiderably heated in contact with vital air, and is by that means entirely converted into the acid which has been called fixed air. Carbone, or coal, appears to be ſoluble in alkalis and in inflammable air, it unites with ſeveral of the metals, particularly iron, with which it forms ſteel when the proportion of coal is extremely ſmall, and plumbago, or blacklead, when the proportion is ſomewhat more than ten times that of the metal. It is a remarkable fact, that theſe two combuſtible ſubſtances, iron and coal, are very difficult of accenſion when thus combined, ſo that plumbago is an uſeful material for melting pots.

Though carbone or coal is not very readily combuſtible, its attraction for vital air is ſtronger than that of any other known ſubſtance, at temperatures above ignition. Hence it reduces metals and various acids to their original ſtate of combuſtibility by attracting the vital air they may have combined with during calcination or acidification.

The laſt claſs of ſimple combuſtible bodies is occupied by the metals; theſe are diſtinguiſhable from all other bodies by their great ſpecific gravity, and

their

their opake ſhining appearance. They are all fuſible, cryſtallizable, and combuſtible, many of them burn with actual exhibition of flame, but none of them are ſo combuſtible as to maintain their own ignition in air no purer than that of our atmoſphere. In vital air ſeveral of the metals ignited at one extremity, become completely burned throughout by the ſucceſſive propagation and developement of the heat. When a metal has undergone combuſtion, its abſolute weight is greater than before, though its ſpecific gravity is leſs. In this ſtate it no longer ſhines, but has the dull appearance of an earth, and is diſtinguiſhed by the name of a calx. Some of the metals are acidifiable. Metallic calces are ſoluble in acids, and form ſalts. Such metals as are not calcinable to any ſenſible degree by mere heat with acceſs of air, are called perfect metals, ſuch as are calcinable by fire are called imperfect: metallic ſubſtances that may be extended by hammering, are called metals, in contradiſtinction to ſuch as are more or leſs brittle, and are called ſemi-metals. All metallic ſubſtances conduct the electric matter with great facility.

Of the metals hitherto diſcovered, the perfect are gold, platina, ſilver, and mercury, or quickſilver; the imperfect are lead, copper, iron, and tin; the ſemi-metals are biſmuth, nickel, regulus of arſenic, cobalt, zink, regulus of antimony, regulus of mangancſe, regulus of wolfram, and regulus of molybdena.

CHAP.

CHAP. IX.

OF THE VITRIOLIC ACID, AND COMBINATIONS WHEREIN IT IS A PRINCIPAL PART.

B THE vitriolic acid, is ſo denominated becauſe
obtained from the ſalt called vitriol. It is uſually
obtained by combuſtion of ſulphur. Sulphur is
either found native in the neighbourhood of vol-
canoes, or united with earths or metals. One of
C the moſt common ſulphureous compounds is the
pyrites, or mundic. This conſiſts uſually of ſul-
phur, iron, clay, and ſiliceous earth. It is gene-
rally of a yellow or greyiſh colour, of a globular or
cubic ſhape, internally radiated, or ſometimes la-
mellar. With the ſteel it ſtrikes fire plentifully,
whence its name is derived. If pyrites be expoſed
to heat in cloſed veſſels, the ſulphur ſublimes; but
in the open air it is decompoſed by combuſtion,
the quantity and combination of the principles left
in the maſs being by that means changed.

D The pyrites, by long expoſure to the action of
the air and moiſture, ſuffer a remarkable change
in their component parts. The ſulphur, by a ſlow
proceſs analogous to combuſtion, becomes acidified,
attracts water, and unites with the iron, forming vi-
triol, and with the clay, forming alum (164, 1).
Theſe may be obtained by ſolution in water; and a
ſubſequent evaporation diminiſhes the quantity of
the

the solvent, so as to cause the salts to separate in the form of crystals.

If vitriol be exposed to distillation, the water that entered into the composition of the crystals rises, and afterwards the greatest part of the acid, with some excess of sulphur combined with it, leaving a brown mass in the retort, called colcothar. A second distillation, with less heat, separates the sulphureous acid, and leaves the dense concentrated vitriolic acid behind.

This process for obtaining the vitriolic acid is not now used, because a cheaper method has been contrived for procuring it immediately from sulphur. A quantity of sulphur and nitre grossly mixed, are placed in a vessel within a small chamber or room, lined with lead, and containing some few inches of water on its bottom. The sulphur is lighted, and the room closed. The nitre serves to maintain the combustion, by supplying pure air, and the vitriolic acid is thus volatilized in the form of air, which (169, w) combines with the water. To expedite this combination, it is said that steam of water is introduced into the closed room during the combustion. By a repetition of the process, the water becomes more and more acid. The redundant sulphur is either dissipated or acidified by exposure to air, and the acid is then concentrated by distilling off the superfluous water.

Vitriolic acid is dense, colourless, and has a stronger tendency to combination in most cases than every other acid. It may be so far deprived

of water as to become concrete, but it attracts this fluid ſo powerfully as to deliqueſce by expoſure to the atmoſphere in a ſhort time, and does not ceaſe to attract the humidity of the air till it has acquired more than ſix times its original weight. In caſes where a certain quantity of air is required to be diveſted of its moiſture, it may be performed by placing a cup, containing concentrated vitriolic acid, under the receiver that confines the air.

H. This acid, and, indeed, every other chemical principle, is beſt known by the phenomena it preſents, and the combinations it produces when united to other bodies. The moſt common of theſe are here enumerated. The names are given according to the Nomenclature of Bergman, who converts the name of the acid in any combination into an adjective, which he applies to the baſe or other principle: ſuch other ſynonimes are likewiſe added as are moſt commonly uſed by chemical or medical writers.

I If the vitriolic acid be poured into a ſolution of the vegetable alkali, to ſaturation, which may be determined by a ſmall quantity of the liquid producing no change of colour with the tincture of heliotropium (158, o) a neutral ſalt is formed that aſſumes the figure of cryſtals, as the water is diminiſhed by evaporation. This is called vitriolated vegetable alkali, or vitriolated tartar, and contains thirty-one parts of acid, ſixty-three of alkali, and ſix of water. It is not eaſy of ſolution in water, requiring ſixteen times its weight to diſſolve it in the

the temperature of 60°; but if the water be boiling, five parts are sufficient. Vitriolated tartar is used only in medicine.

The vitriolated mineral alkali, or Glauber's salt, may be produced in the same manner, by making use of the mineral alkali instead of the vegetable. It contains fourteen parts of acid, twenty-two of alkali, and sixty-four of water, and resembles vitriolated tartar in many of its properties, but requires only three times its weight of water to dissolve it at the temperature of 60°. Great part of the water that enters into the formation of the crystals is dissipated by exposure for some time to the air, the salt gradually falling into a white powder or efflorescence. K

Vitriolated volatile alkali, or vitriolic ammoniac, contains forty-two parts acid, forty of alkali, and eighteen of water. L

Vitriolated lime, commonly called selenite, abounds in vast quantities in nature, and accordingly as its external appearance and texture differs, it is called gypsum, lapis specularis, alabaster. In the temperature of 60° it requires about five hundred times its weight of water to dissolve it, and from thence was formerly reckoned among the earths, though its component parts are thirty acid, thirty-two earth, and thirty-eight water. By exposure to heat a little below ignition, about twenty parts of its water are dissipated, at the same time that it falls into a powder, which is agitated by the vapours that escape in such a manner as to cause M

the appearance of boiling. This powder is known in commerce by the name of plaſter of Paris, and is chiefly uſed for making ſtatues, and other articles that receive their figure from a mould; an uſe to which it is admirably adapted, by the ſpeedy reſumption of a ſolid form, when the water of cryſtallization is reſtored: for, if the powder be mixed with water, to the conſiſtence of thin paſte, it may be poured into a mould, and will run into all the ſtrokes and cavities with the greateſt facility; a few minutes after which, the water that maintained the ſtate of fluidity, by mere mixture with the powder, combines intimately with it, and the whole maſs becomes ſolid.

N Vitriolated ponderous earth, or marmor metallicum, already deſcribed, (162, c) contains eighty-four parts of earth, thirteen of acid, and three of water; in the native ſpecimens it is inſoluble, or nearly ſo in water.

O Vitriolated magneſia, or Epſom ſalt, contains twenty-four parts of acid, nineteen of earth, and fifty-ſeven of water. It effloreſces like Glauber's ſalt, by expoſure to the air, and requires about its own weight of water to diſſolve it in the temperature of 60°.

P Vitriolated clay, or alum, contains twenty-four parts of acid, eighteen of earth, and fifty-eight of water. Its cryſtals are uſually covered with a ſlight efflореſcence. In about fifteen times its weight of water, at the temperature of 60°, it is totally diſſolved; but at higher degrees of heat it is ſoluble in a

very

very small quantity of that fluid. It is fused even by its own water of crystallization, and boils up into a frothy mass, which gradually dries into a white friable substance, called calcined alum. Calcined alum is, however, no otherwise changed than by the loss of its water, and may be reduced again into its original form by restoring it.

The combination of sulphur with a fixed alkali may be made either in the dry way, by melting the two substances together, or in the moist way, by boiling sulphur in an alkaline lixivium, and evaporating the water. This last method is, however, seldom made use of. The liver of sulphur, so called from its colour, has a fetid smell, is soluble in water, and is very deliquescent.

The combination of sulphur and alkali attracts water from the atmosphere which it decomposes, the vital air of the water combines and acidifies the sulphur, while the inflammable air flies off in combination with another portion of the sulphur, which constitutes hepatic air, so that at length the alkali remains united only to the acid, forming either vitriolated tartar or Glauber's salt. The attraction exerted in this case between sulphur and alkali is much weaker than it would have been if the former had been acidified. For, if the liver of sulphur be dissolved in water, the alkali will be attracted and the sulphur precipitated, on the addition of an acid, whose elective attraction to the alkali is much less powerful than that of the vitriolic acid when perfectly formed.

The method of Stahl for producing ſulphur, by what was called the direct combination of the vitriolic acid with the principle of inflammability, deſerves to be mentioned in this place. Equal parts of vegetable fixed alkali, and vitriolated tartar, are fuſed in a crucible, after which ſomewhat leſs than one-fourth part of charcoal in powder is added, and the whole well mixed by ſtirring. The crucible is then covered, and a ſtrong heat given for a very ſhort time; after which it is taken from the fire, and the contents poured on a ſmooth ſtone, previouſly ground. This matter is not then found to differ in its eſſential properties from the liver of ſulphur, and if diſſolved in water, the ſulphur may be precipitated by the addition of an acid. The theory of theſe facts was ſtated to be, that the phlogiſton of the charcoal combined with the concentrated acid of the vitriolated tartar, and forms ſulphur, which unites with the alkali in the ſame manner as other ſulphur would have done if directly added. The modern theory is ſimply that the charcoal attracts the vital air, which is one of the component parts of the acid, and leaves the ſulphur, which is the other component part.

The vitriolic acid, in combination with metallic calces, forms ſalts which have been denoted under the general name of vitriols. The three following only are known in commerce, or uſed in the arts.

Vitriolated iron, or martial vitriol, known vulgarly by the name of green copperas, contains, when

when recently cryſtallized, twenty parts of acid, twenty-five of iron, and fifty-five of water; but it effloreſces by the loſs of part of its water when expoſed to the air. It requires ſix times its weight of water to diſſolve it in the temperature of 60°. This ſalt is uſed in dying blacks, and in making ink for writing.

Vitriolated copper, or blue vitriol; of this v
thirty parts in the hundred are acid, twenty-ſeven copper, and forty-three water. It is uſually obtained from waters in Hungary, Sweden, or Ireland, in which it is naturally diſſolved. It requires about four times its weight of water to diſſolve it in the temperature of 60°. In ſome places w
the waters naturally containing this ſalt are made to depoſit the copper by expoſing pieces of iron to their action. For the acid quits the copper, and forms martial vitriol, by uniting with the iron, which receives the neceſſary portion of vital air from the calx of copper, which conſequently reſumes its metallic ſtate. The martial vitriol being ſoluble, remains in the water, while the copper falls to the bottom in a muddy or powdery form. If the ſolution, or water containing vitriolated copper, has no conſiderable exceſs of acid, eighty parts of iron will precipitate one hundred of copper. One of x
the teſts of the preſence of vitriolated copper in a liquid conſiſts in dipping a piece of clean bright iron therein, which becomes immediately covered with a thin coat of copper, in conſequence of the

beginning of the procefs of transferring the acid from one metal to the other.

Y Vitriolated zink, vulgarly called white vitriol, or copperas, is of a white colour, and contains twenty-two parts of acid, twenty of zink, and fifty-eight of water. It is foluble in about twice its weight of water at the temperature of 60°.

Z If the concentrated vitriolic acid be heated with almoft any inflammable fubftance, part of the vital air of the acid combines with and burns the fubftance, while another part of the acid having thus a redundant portion of fulphur, flies off in the form of vitriolic acid air. This air may be confined by mercury, but unites with water, forming the volatile vitriolic acid (172, F). Vitriolic acid air is fatal to animals.

A In proceffes with fome of the metals, efpecially iron and zink, the vitriolic acid, when properly diluted, is not decompofed, but the vital air for calcination of the metal is fupplied by the water itfelf. The other principle of the water, namely inflammable air, therefore flies off inftead of vitriolic acid air, which in this cafe is not extricated.

CHAP.

CHAP. X.

OF THE NITROUS ACID, AND COMBINATIONS WHEREIN IT IS A PRINCIPAL PART.

NEITHER the nitrous acid, nor any of the ſalts containing it, are ever found in conſiderable quantities in nature. This acid is obtained by the complete putrefaction of animal or vegetable ſubſtances; in which it is produced by the combination of the vital air of the atmoſphere with phlogiſticated air from the organized ſubſtances. Grounds frequently trodden by cattle, and impregnated with their excrements, or where vegetables rot, or in the vicinity of ſlaughter-houſes, or burying-grounds, or other places expoſed to putrid vapours, afford nitre after long expoſure to the air. The earths that afford the beſt matrix for the reception and complete putrefaction of the vegetable or animal matter, are of the calcareous kind; and in ſome places artificial beds, compounded of putreſcent matter and calcareous earth, are made with ſucceſs for the production of nitre. If theſe beds contained much vegetable matter, a conſiderable portion of the ſalt obtained from them is true nitre, or the nitrous acid combined with the vegetable alkali; but if otherwiſe, the nitrous acid is, for the moſt part, combined with calcareous earth, and requires the addition of the vegetable alkali

to

to decompoſe it. With this intention wood-aſhes, or pot-aſh, is uſually added in the proceſs, which is as follows:

D A number of large caſks are prepared, with a cock at the bottom of each, and a quantity of ſtraw within, to prevent its being ſtopped up. The nitrous earth is placed in theſe, together with wood-aſhes, or pot-aſh, either ſtrewed at top, or ſtratified with the other matter. The veſſels are then filled with hot water, which, after ſome time ſtanding, is drawn off, and freſh water added repeatedly, ſo long as any ſalt can be extracted by this means. This waſhing of the earth is repeated, by paſſing the ſaline liquor through freſh parcels, till it is ſtrongly impregnated. In this ſtate it is conveyed to the boiler, and great part of the water evaporated by heat. A conſiderable proportion of common ſalt, which the water obtains from the earth, is depoſited during the boiling, and taken out by means of a perforated ladle, while the nitre ſtill remains in
E ſolution. For the quantity of nitre that can be held in ſolution by boiling water is much greater than of common ſalt; therefore, the common ſalt will begin to be thrown down at a much earlier period of the evaporation than the nitre, and a conſiderable portion of the former will be thus ſeparated before any of the latter quits the ſolvent. When the liquor is ſufficiently concentrated by boiling, which is known by trials made with ſmall quantities taken out from time to time, it is con-

veyed

veyed into veſſels where it cools, and much of the nitre is then found in a cryſtallized ſtate.

The ſeparation of the nitre from the common F ſalt is much forwarded by another circumſtance, wherein their ſolubilities differ. Nitre being diſſolved to ſaturation in boiling water, will afford a large quantity of cryſtals by cooling; a proof that it is more ſoluble in hot than cold water: but common ſalt by the ſame treatment affords ſcarcely any. In the foregoing proceſs it is found, that on this account the cryſtals formed by cooling conſiſt almoſt entirely of nitre, the common ſalt remaining diſſolved in the water, notwithſtanding its change of temperature. And a repetition of the proceſs ſerves to purify the nitre ſtill more. With this intention, ſo much pure water is added to the nitrous cryſtals as is barely ſufficient to diſſolve them, and the evaporation by boiling is repeated. The cryſtals of nitre obtained by the ſecond cooling are much purer than before, becauſe the proportion of water to the common ſalt is greater, and conſequently leſs will cryſtallize with the nitre. For nice purpoſes this boiling with freſh water is repeated four times.

If nitre be expoſed to a ſtrong heat in an earthen G retort, a large quantity of air, much purer than that of the atmoſphere, is produced, and the alkaline baſe is left in combination with the earth of the retort, which it diſſolves. The weight of the air thus obtained, added to that of the alkaline baſe, amounts to the whole weight of the nitre made

uſe

H use of*. This fact is variously explained. The pure air is asserted by some to consist of the nitrous acid, deprived of water and phlogiston, and united to heat in a latent state; or of the nitrous acid perfectly saturated with phlogiston; or of the water that entered into the formation of the nitre, and is supposed to be, by some means, dephlogisticated; (148, M, N) or of a principle common to all acids. For the production of pure or dephlogisticated air, also takes place, when certain other salts which do not contain the nitrous acid are exposed to heat.

I A most intense degree of combustion takes place when nitre is brought into contact with any inflammable body, either of the two being previously made red hot. This continues either till the whole of the nitrous acid is dissipated, or the body consumed, and is evidently owing to the pure air produced, which maintains the combustion. In the detonation of nitre with combustible bodies, water is produced, formerly termed the clyssus of nitre, and most probably afforded by the combination of the inflammable air of the body consumed with the vital air of the nitre, (148, N).

K Gunpowder is usually composed of 75 parts nitre, sixteen charcoal, and nine sulphur, intimately blended together, by long pounding in wooden mortars, with a small quantity of water. Its effects are well known. Any part of a quantity of gunpowder being set on fire, the detonation begins, and

* Berthollet, in the Memoirs of the Royal Academy of Paris for the year 1781.

is propagated with amazing rapidity through the interſtices of the grains. In conſequence of which, a ſudden and very powerful expanſion of the materials takes place.

Nitre, or nitrated vegetable alkali, contains L
thirty parts acid, ſixty-three alkali, and ſeven water. It requires about ſeven times its weight of water to diſſolve it in the temperature of 60°.

If concentrated vitriolic acid be poured a little at M
a time on pure nitre, in a tubulated retort, with a large receiver, taking care immediately to cloſe the aperture, it will combine with the alkali, and the nitrous acid, called ſpirit of nitre in commerce, will riſe in fumes that will become condenſed in the receiver. After the ſpontaneous vapours have ceaſed, heat muſt be gradually applied, till nothing more will come over. Vitriolated tartar (173, I) will remain in the retort, and if the acid in the receiver be added to pure vegetable alkali, it will again compoſe nitre.

This nitrous acid is of a yellow colour, and con- N
tinually emits red ſuffocating fumes. Theſe fumes ariſe from an exceſs of the baſe, which may be driven off, by haſtily boiling the acid in an open veſſel, when the acid becomes as clear as water. But the ſmalleſt addition of any inflammable matter, or even expoſure to the ſun's rays, will reſtore the former colour, and cauſe the acid to emit fumes as before.

Nitrous acid of the ſhops is ſeldom without a O
mixture of the marine acid, which it obtains from the

the ſea-ſalt that cryſtallizes with the nitre made uſe of, (183, D). This may be ſeparated by diſſolving ſilver in a ſmall quantity of the acid, and dropping gradually ſome of this ſolution into the acid required to be purified, as long as any cloudineſs appears. For the marine acid combines with the ſilver, and forms a compound that precipitates to the bottom, leaving the nitrous acid pure.

P The red vapour which riſes from the nitrous acid may be preſerved in cloſe veſſels, without condenſation by cold. It is called the aeriform nitrous acid. Water abſorbs it, which becomes ſucceſſively blue, green, and at laſt yellow, when it has received an increaſe of one-third of its bulk. This has been termed the phlogiſticated nitrous acid.

Q Experiments with the aeriform nitrous acid are rendered difficult, by the circumſtance of its acting on, and uniting with every fluid hitherto uſed in attempting to confine it.

R When nitrous acid is applied to combuſtible bodies, nitrous air is produced. This may be collected in water as well as quickſilver. Nitrous air exhibits no marks of acidity when properly prepared. Water will imbibe one-tenth of its bulk of this air.

S The mixture of nitrous with reſpirable air affords a remarkable and intereſting appearance. Their union is attended with heat; a reddiſh brown cloud appears, and the ſum of the ſpaces occupied by
T both airs becomes much ſmaller than before. It is found that their diminution is greater, the better

ter adapted the reſpirable air is to the purpoſes of ſupporting animal life or combuſtion; and that nitrous acid is precipitated, and becomes diſſolved by the water over which the operation is performed:

Dr. Prieſtley, whoſe diſcoveries reſpecting aeriform fluids have deſervedly placed him in the higheſt rank of experimental philoſophers, uſually aſcertains the purity of air by adding an equal volume of nitrous air to it, and expreſſes the ſame by writing in figures the ſpace occupied by both after the diminution. Thus, if equal meaſures of common and nitrous air were diminiſhed on mixture by $\frac{7}{10}$ of a meaſure, he ſays the meaſure of the teſt is 1.3; which number denotes the reduced bulk of the air which was originally 2. But when the purity of vital air is to be aſcertained, he uſes more nitrous air, a ſingle meaſure not being ſufficient. The pureſt vital air will receive the addition of three times its own bulk of nitrous air before the ſpace it occupies is ſenſibly augmented. u

The inſtruments uſed to determine the ſalubrity of air by this method are called eudiometers. In general, experiments may be made with a graduated tube A B, fig. 158, on which the ſpace occupied by the air after its diminution may be read by means of the diviſions. v

If a mixture of two parts by meaſure of vital air obtained without the uſe of nitrous acid, and one of phlogiſticated air or azote, or which is the ſame thing, five parts of vital and four of common air,

air, be expoſed to the action of the electric ſpark in the upper part of a ſyphon in which it may be confined by mercury, and a ſmall quantity of ſoap lees or ſolution of pure vegetable alkali be admitted into the cavity which contains the air, an abſorption will take place, and nitrous acid will be produced, as appears by the alkali being converted into true nitre. This is a ſlow operation, and requires the quantity of air in the ſyphon to be renewed very often to ſupply the abſorption*. It has likewiſe been found that this acid is produced by expoſing vital air for a long time to the exhalations of putrifying animal ſubſtances, together with calcareous earth, or any other proper baſe to receive and combine with it †. There can be little doubt but the putrid exhalations conſiſting chiefly of phlogiſticated air, it appears therefore that this ſubſtance bears the ſame relation to the nitrous acid, as ſulphur does to the vitriolic. As ſulphur by combuſtion, in which vital air is an indiſpenſable requiſite, becomes converted into vitriolic acid, ſo phlogiſticated air becomes converted into nitrous acid, though on account of its being leſs combuſtible, the red heat cannot be produced and kept up without the co-operation of electricity; and as ſulphur when in contact with the pure air of

* For the detail of the particulars of this moſt curious experiment, conſult Mr. Cavendiſh's papers in the Phil. Tranſ. Vol. 75. p. 372, and Vol. 78. p. 255.

† This is the diſcovery of Mr. Thouvenel. See his prize diſſertation on the formation of Nitre.

the

atmoſphere and with a baſe proper for combining with the vitriolic acid is converted into that acid by a ſlow combuſtion in the pyrites; ſo the like expoſure of phlogiſticated air in contact with calcareous earth to vital air, produces nitrous acid, though much more ſlowly, becauſe the baſe is leſs combuſtible.

The nitrous acid, with the mineral alkali, forms w
nitrated mineral alkali, or quadrangular nitre, which contains thirty parts of acid, ſixty-three alkali, and ſeven water. Its properties are nearly the ſame as thoſe of the common, or priſmatic nitre, but it is leſs fit for making gunpowder, becauſe it attracts humidity from the air. About three times its weight of water at the temperature of 60° are ſufficient to hold it in ſolution.

Nitrated volatile alkali, or nitrous ammoniac, x
contains forty-ſix parts acid, forty alkali, and fourteen water. This ſalt is remarkable for its property of detonating, without the contact of inflammable matter, when heated over the fire; which is one of the proofs that the volatile alkali contains inflammable matter.

Nitrated lime, or nitrous ſelenite, contains y
thirty-three parts acid, thirty-two earth, and thirty-five water. It is deliqueſcent.

With ponderous earth the nitrous acid forms a z
ſalt, whoſe cryſtals do not deliqueſce.

Nitrated magneſia is a deliqueſcent ſalt, and A
contains thirty-ſix parts of acid, twenty-ſeven of magneſia, and thirty-ſeven of water.

B Nitrated clay appears to be of very difficult ſolution in cold water, and may contain 153 parts of acid to 100 of earth*.

C The nitrous acid diſſolves moſt metallic ſubſtances, part of the acid flying off in the form of nitrous air, and the reſt in combination with the metallic calces, forming ſalt.

D The inflammation of oils, by the affuſion of the nitrous acid, is a phenomenon that never fails to excite the aſtoniſhment of the beholders. All the oils obtained by diſtillation from vegetables, and diſtinguiſhed by the name of eſſential oils, and alſo ſuch other oils as are diſpoſed to become thick and dry, by expoſure to the air, are proper for this ex-
E periment. An ounce of the oil intended to be ſet on fire muſt be placed in a ſhallow veſſel, and a bottle containing an ounce of the moſt concentrated nitrous acid muſt be faſtened at the end of a pole, that the operator may be ſufficiently diſtant from the inflammation. Two thirds of the acid being poured on the oil, excites a conſiderable ebullition; the oil grows black and thick, and ſometimes inflames. But if this laſt circumſtance does not happen in four or five ſeconds, the remainder of the acid muſt be poured where the mixture appears the moſt dry and black, and then the inflammation ſcarcely ever fails taking place.

F Fat oils may alſo be inflamed, if equal parts of the nitrous and vitriolic acids be firſt poured on them, and, when the ebullition is at the greateſt, a portion of nitrous acid be poured on the dryeſt part.

* Kirwan in Philoſ. Tranſ. for 1782.

The theory of this ſingular experiment is yet imperfect. There can be little doubt but the vital air of the nitrous acid (182, G) combining with the inflammable matter, produces the combuſtion (150. T, U). But the other circumſtances relating to the capacities the new combinations in this proceſs may ſeverally have for heat, and on which the high temperature produced in a great meaſure depends, have not yet been ſufficiently inveſtigated. It is probably owing to theſe that eſſential oils are better adapted to this purpoſe than any other phlogiſtic bodies. The vitriolic acid may perhaps tend to concentrate the nitrous acid in the experiment with fat oils, or perhaps its action on the oils may bring them nearer to the nature of eſſential oils, at leaſt as far as it relates to this proceſs. G

CHAP. XI.

OF THE MARINE ACID, AND COMBINATIONS WHEREIN IT IS A PRINCIPAL PART.

The marine acid is obtained from common ſalt. This ſalt, ſo univerſally uſed throughout the civilized parts of the world, is either dug out of the earth in large maſſes, called rock-ſalt, or obtained by evaporation from the waters of ſalt-ſprings, or of the ſea. Sea-water uſually contains between the twenty-fifth and thirtieth part of its weight H

of this ſalt, together with other magneſian or cal-
K careous ſalts in much ſmaller quantities. In hot countries the water is evaporated ſo as to afford the ſalt in cryſtals, by mere expoſure to the action of the ſun and wind, in large receptacles, formed in the ground near the ſea-ſide, and into which the
L water can be admitted at the tide of flood. In the ſouth of France, and other parts of the world, they collect and dry the ſea-ſand, from which a ſtrong brine is afterwards obtained, by paſſing ſuch a quantity of water through it, as is merely ſufficient
M to diſſolve the ſalt that adheres to the grains. The intenſity of cold in northern countries is alſo made uſe of for this purpoſe, where the ſea-water being expoſed to freeze, the ice is found to conſiſt almoſt entirely of freſh water, and conſequently, upon being taken out, leaves the brine much
N ſtronger. In theſe laſt-mentioned caſes, as well as in more temperate climates, the cryſtals are obtained by boiling the brine in proper veſſels over the fire.

O If the vitriolic acid be poured on ſea-ſalt, it combines with the alkali (143, c) while the marine acid flies off in the form of marine acid air. This air is colourleſs, and permanently elaſtic when confined by mercury, but has a ſtrong tendency to unite with water. When it eſcapes into the atmoſphere, it has the appearance of white fumes, on account of the moiſture it meets with, and unites
P to. The common marine acid conſiſts of water

impregnated

impregnated with this air, which it readily gives out on the application of heat.

In the method formerly uſed of procuring the marine acid by diſtillation from common ſalt with the vitriolic acid, much of the marine acid air was loſt, for want of water to combine with. This is now remedied, by applying a ſecond receiver *, containing water, into which a tube, proceeding from the upper part of the firſt receiver, is immerſed. The marine acid air that eſcapes uncondenſed from the firſt receiver combines with the water in the ſecond, and converts it into ſtrong marine acid. Q

The marine acid of the ſhops is of a light yellow colour, and continually emits ſuffocating fumes. The colour, however, is not eſſential to it, but ariſes from the ſolution of ſome impurities in the common proceſs for making it. R

Black mangeneſe is the calx of a ſemimetal, (170, A) which contains a large portion of vital air, which it is diſpoſed to give out. If four ounces of concentrated marine acid, with one ounce of this calx, be put into a tubulated retort, to which the apparatus of receivers uſed (190, Q) in diſtilling the marine acid has been previouſly adapted, yellow vapours are abundantly diſengaged, at firſt without the aſſiſtance of fire, and afterwards by means of heat. The water in the ſecond receiver becomes impregnated with theſe fumes, of which, however, it abſorbs a very ſmall quantity. If the temperature be near freezing, the elaſtic fluid, after ſaturat- S

* The invention of Mr. Woulfe.

ing the water, takes a concrete form, and gradually subſides to the bottom: but a very ſlight degree of warmth raiſes this ſubſtance in the form of bubbles, which endeavour to eſcape.

T As this vapour combines with water, and has likewiſe a powerful action on mercury, it has not been confined ſo as to retain its elaſtic ſtate.

U It is found to conſiſt of the marine acid, combined with an exceſs of vital air. It attacks combuſtible bodies with great vehemence, and diſſolves all the metals directly, affording the ſame ſalts as the entire acid does, but without diſengaging any inflammable air. It whitens vegetables and wax, and produces in many ſubſtances changes ſimilar to ſuch as ariſe from long expoſure to air. When united to water, its taſte is auſtere, but not acid; but it regains all the properties of the marine acid when again deprived of its exceſs of vital air by action upon combuſtible matter.

V A mixture of the nitrous and marine acids, or of the nitrous acid with common ſalt, or ſal ammoniac, is called aqua-regia, from its property of diſſolving gold. The power of this ſolvent on gold is ſuppoſed to conſiſt in the marine acid, which is thought to be ſupplied with vital air from the nitrous, and is found alone in the cryſtals of ſalt produced in the combination of metallic calx and acid. There ſeems, however, to be ſome other circumſtance concerned here; for it is not eaſy to ſay why the nitrous acid alone cannot calcine the gold, if its diſpoſition to part with vital air, be greater

greater than that of the aerated marine acid; and if this were not ſo, how could it afford the ſuppoſed exceſs to this laſt acid. But it is no uncommon appearance in chemiſtry for the properties of compounds to be very different from thoſe of either of the component parts.

Salited mineral alkali, or common ſalt, contains thirty-three parts acid, fifty alkali, and ſeventeen water. Its cryſtals are quadrangular, and do not deliqueſce in the air. w

Salited vegetable alkali, or ſalt of Sylvius, contains thirty parts acid, ſixty-three vegetable alkali, and ſeven water. It does not deliqueſce in the air, and is ſoluble in about three times its weight of water. x

Salited volatile alkali, or common ſal-ammoniac, contains fifty-two parts acid, forty volatile alkali, and eight water. It diſſolves in about three and a half times its weight of water, at the temperature of 60°. By heat it ſublimes unaltered, or nearly ſo. y

Salited lime, or marine ſelenite, contains about forty-two parts acid, thirty-eight earth, and twenty water. It deliqueſces in the air.

Salited ponderous earth is little known; its ſolution affords a valuable method of purifying the marine acid from the vitriolic, with which it is often adulterated. For, upon the addition of this to the marine acid under examination, the vitriolic acid, if preſent, ſeizes the ponderous earth, and forms the vitriolated ponderous earth, which being nearly z

insoluble, falls to the bottom *. The exact quantity necessary to be added is known by trials on small portions of the acid.

A Salited magnesia, or marine Epsom, is a deliquescent salt, found in greater quantity in the water of the sea than any other, except common salt.

B Salited clay is a deliquescent salt, and may contain 174 parts acid, to 100 of earth.

C The marine acid acts directly on, and combines with tin, lead, copper, iron, zinc, and bismuth, and with the other metals, by proper management, forming salts, possessed of various properties.

CHAP. XII.

CONCERNING THE ACIDS OF FLUOR, OF BORAX, OF AMBER, AND OF PHOSPHORUS.

D FUSIBLE spar or fluor, better known in England by the name of Derbyshire spar, consists of a peculiar acid, called the sparry acid, combined with calcareous earth and water. This spar is either transparent or opake, of different colours, and generally has a cubic, rhomboidal, or polygonal figure. Most specimens, especially the coloured, have the property of becoming phosphorescent, or emitting light, when heated far below ignition, as may be done by laying them on a hot

* Withering in Philos. Trans. Part II. for 1784.

iron; but they lose this property by being made red-hot. It does not strike fire with steel, nor effervesce with acids. The calcareous earth is fifty-seven parts in the hundred, and the rest acid and water.

If an equal weight of concentrated pure colourless vitriolic acid be poured, by means of a tube, on pulverized fluor, in a retort, a decomposition of the fluor takes place with heat. The vitriolic acid seizes the calcareous earth, and the fluor acid escapes in the form of air, of a most penetrating smell, which may be confined by mercury, but unites with water in very considerable quantity. If the acid be wanted in a fluid state, it is necessary to adapt a receiver, containing water, about ten or twelve times the weight of the spar. This acid, especially when heated, and in the aerial form, dissolves, and retains siliceous earth, which it takes from the glass-vessels during the distillation, soon corroding them through, if they be not very thick. The fluor acid air deposits some of this earth by cooling; and the greatest part in the form of a white crust on the surface of water, when it combines with that fluid. In order to obtain the acid free from siliceous earth, it is convenient to use leaden vessels. E F G

H The saline combinations formed by uniting this acid with alkali, earths, or metallic calces, clearly shew that it is a peculiar acid, as different in its properties from all other acids as they are from each other.

I Borax is a salt, imported from the East Indies,

in

in the form of hexangular, or irregularly figured cryſtals, of a dull white, or greeniſh colour, and greaſy to the touch. In this ſtate it is called tincal. It is dug out of the earth in the kingdom of Thibet, in a cryſtallized ſtate. The impurities are ſeparated by ſolution, filtration, and cryſtallization.

K This ſalt requires about eighteen times its weight of water to diſſolve it in the temperature of 60°. When heated, it ſwells up, loſes its water of cryſtallization, and runs into a kind of glaſs, which may be again diſſolved in water. It is chiefly uſed as a flux for ſoldering metals.

L The component parts of purified borax are, ſeventeen parts of mineral alkali, thirty-four of a peculiar acid called the acid of borax, or ſedative ſalt, and forty-ſeven of water. In this combination not more than about five parts of the alkali are really ſaturated, for which reaſon borax in many caſes acts as an alkali.

M If borax be diſſolved to ſaturation in water, and the vitriolic acid be added, this laſt will combine with the alkali, and diſengage the ſedative ſalt, which will ſwim at the ſurface, in the form of white ſcales. The filtered liquor will yield vitriolated mineral alkali, or Glauber's ſalt. This acid is alſo obtained by ſublimation; the alkaline baſe being ſeparated by the previous addition of ſome ſtronger acid.

N The acid of borax requires fifty times its weight of water to hold it in ſolution. Its acid properties when uncombined are but weakly manifeſted. A moderate

moderate heat melts it with leſs intumeſcence than
borax, but the glaſs ſo formed is again ſoluble in
water. This fixed acid may be uſed for the ſame
purpoſe as borax, and is a moſt uſeful flux in experi-
ments to be made with the blow-pipe. It has been
found uncombined in the waters of certain lakes in
Tuſcany.

Amber is a ſubſtance dug out of the earth O
more abundantly in the Pruſſian dominions than
elſewhere. The moſt valuable ſpecimens are of a
clear tranſparent yellow. Its origin is probably
from the vegetable kingdom, as it is almoſt always
found in the neighbourhood of foſſil wood. By diſ-
tillation an acetous liquor, an oil, and a concrete P
acid, are obtained; which laſt may be ſomewhat
purified by ſolution and cryſtallization. The combi-
nations of this with alkalis, earths, or metals, denote
it to be a peculiar acid.

Phoſphorus (170, Y) till lately has been ob- Q
tained by diſtillation from urine only, the water, and
other more volatile parts, having been previouſly
diſſipated by heat in an open veſſel. Towards the
end of this proceſs, which requires a ſtrong fire of
ſeveral hours continuance, the phoſphorus comes
over, and paſſes into the receiver, which muſt be
half filled with water. But it is now known, that R
the phoſphoric acid exiſts not only in all the ſolid
parts of animals as well as in urine, but alſo in ve-
getables, and is found in the mineral kingdom, com-
bined with lead, and with iron. The fixed parts of S
the

the bones of animals is found to contain this acid, united to calcareous earth.

T If the bones of animals be burned in the fire till they have become white, they are in a proper ſtate to afford the phoſphoric acid. Three parts by weight of this matter in powder may be gradually added to two parts of concentrated vitriolic acid, and afterwards about five parts of water. This mixture muſt be left to digeſt for a day, water being added occaſionally to ſupply what evaporates, at the end of which time more water muſt be plentifully added, and the liquor ſtrained through a fine ſieve. What remains in the ſieve is gypſum, or vitriolated lime. The liquor, by evaporation to dryneſs, leaves a reſidue, conſiſting in a great meaſure of the phoſphoric acid, which has been diſengaged from its calcareous baſe by the vitriolic acid. This reſidue, urged by a ſtrong heat, flows into a kind of glaſs of a whitiſh ſemiopake appearance. It is not, however, neceſſary, for the making of phoſphorus, to carry the evaporation farther than till the matter has acquired the conſiſtence of ſyrup; which may be conveniently performed in a copper veſſel.

U Equal parts of this liquid, and of charcoal in powder, mixed together, afford phoſphorus by diſtillation in a good earthen retort (132, c). The receiver muſt be half filled with water, and muſt have a ſmall hole pierced in its upper part, to let the elaſtic vapours eſcape; or, inſtead of a receiver, the neck of the retort may ſimply be plunged in

water

water contained in an open baſon. When the retort is red-hot, the phoſphorus will enter the receiver in drops, which ceaſing, the whole apparatus muſt be ſuffered to cool. The phoſphorus, which is in ſmall maſſes, reſembling reddiſh wax, or tallow, muſt be preſſed together under water, particular care being taken that none remains ſticking to the hands or under the nails, as a ſmall particle, taking fire when brought into the air, in ſuch a caſe, might be attended with very diſagreeable conſequences. It may be moulded into ſticks, by putting the pieces under water into ſmall upright tubes of glaſs, rather conical, and ſtopped at the lower end, and on heating the water, the phoſphorus will melt and take the deſired forms. The impurities that riſe to the upper ends of the tubes, may be cut off when taken out of the water, which muſt not be done till all is cool; or, it may be had exceedingly pure by ſtraining it through a leather bag immerſed in hot water. But the beſt method of clearing phoſphorus from the impurities of the firſt diſtillation is to diſtil it again with a very gentle heat.

To prevent the ſpontaneous combuſtion and acidification of phoſphorus, it muſt be kept in a bottle with water ſufficient to cover it. v

The phoſphoric acid may be had combined with water, by placing ſticks of ſolid phoſphorus in a glaſs funnel, inſerted in the neck of a bottle containing water. A piece of glaſs tube, inſerted in the neck of the funnel, will prevent the ſticks from falling through. In this ſituation, if the temperature be moderately w

moderately warm, the phoſphorus will be gradually decompoſed by the ſlow combuſtion (170, Y), and afford its acid to the water. The acid thus obtained is contaminated with phoſphorus, but becomes gradually leſs ſo by expoſure to the air.

X Heat drives off the water from the phoſphoric acid, ſo as to convert it into a ſolid tranſparent ſubſtance of an acid taſte, which deliqueſces by attracting the moiſture of the atmoſphere, and diſſolves in water, at the ſame time producing heat.

Y When urine is brought to the conſiſtence of ſyrup by evaporation, a ſalt is obtained in cryſtals, called fuſible ſalt of urine, or microcoſmic ſalt, at firſt vitiated by an addition of extractive matter and common ſalt; but which may be purified by ſubſequent ſolution, filtration, and cryſtallization. This ſalt conſiſts of the phoſphoric acid, combined in part with the volatile alkali, and in part with the mineral alkali. If microcoſmic ſalt be expoſed to heat, the volatile alkali is driven off, while the phoſphoric acid and mineral alkali remain fixed, and fuſe together into a glaſs that affords phoſphorus by diſtillation with charcoal (198, V).

Z The mineral alkali in this glaſs prevents a conſiderable portion of the acid from being converted into phoſphorus, forming with it a compound which has the properties of an acid. In this ſtate it is convertible into glaſs by the action of heat, and effloreſces by expoſure to the atmoſphere. It is ſoluble in leſs than twice its weight of hot water, and cryſtallizes by cooling. Bones afford it as well as urine.

CHAP.

CHAP. XIII.

OF THE ACIDS OF SUGAR, OF SORREL, OF LEMONS, OF BENZOIN, OF MILK, OF SUGAR OF MILK, OF ANTS, OF FAT, AND OF PRUSSIAN BLUE.

SUGAR is a saline substance, obtained from most, if not all, nutritive vegetable substances, but most plentifully, or at least most usually, from the sugar-cane, which is cultivated in the warmer climates for that purpose. In the settlements of the Europeans the cane is crushed, by passing it between wooden rollers, which compress it to such a degree, that the vegetable fibres pass through, leaving most of the juices behind, which run into vessels, or troughs, properly placed to receive and conduct them to the boilers. The addition of alkaline ley and lime-water is necessary to the crystallization of the sugar, which takes place in consequence of the evaporation by boiling. Repeated solutions, and boiling in lime-water and ley, with the addition of oxes blood, or whites of eggs, for the purpose of separating the impurities in the form of skum, render the sugar more white and pure. The inspissated liquor, containing the sugar, is poured into conical earthen moulds, where it crystallizes, and the treacle is let out, by drawing a plug from an aperture in the bottom.

bottom. A ſtill greater degree of purification is obtained by ſpreading an argillaceous paſte over the top of the ſugar, great part of the remaining treacle being carried down by the moiſture that ſlowly penetrates the maſs.

B A very ſlow cooling of a ſolution of ſugar, in a heated room, cauſes it to ſhoot into large cryſtals, called ſugar candy. In other caſes the cryſtals are ſmall and irregular.

C The analyſis of this ſalt is yet imperfect. By diſtillation alone it affords acid and an empyreumatic oil, leaving a conſiderable reſidue. The ſalt called acid of ſugar, is, however, obtained by another proceſs.

D Let three ounces of ſtrong nitrous acid, whoſe ſpecific gravity is nearly 1.567, be mixed in a tubulated retort, with one ounce of the fineſt ſugar in powder, to which, after the ſolution is completed, and the moſt phlogiſticated part of the nitrous acid flown off, let a receiver be adapted, and the liquid gently boiled. As ſoon as it has acquired a dark brown colour, three ounces more of nitrous acid muſt be added, and the boiling continued till the coloured ſmoking acid has entirely diſappeared. The liquor in the retort muſt then be poured out into a larger veſſel, and will by cooling afford ſmall quadrilateral cryſtals, which, collected and dried on bibulous paper, weigh 109 grains. The remaining lixivium boiled again in the retort, with two ounces of nitrous acid, affords 43 grains of cryſtals by cooling. Nitrous acid, in

in the whole amounting to two ounces, being added, by small portions at a time, to the glutinous liquid remaining from the last crystals, and then evaporated to dryness, a saline mass is obtained, which contains about fifteen grains of crystals. All these products, but more particularly the last, require to be depurated by repeated solutions and crystallizations in pure water.

Neither the quantities nor the strength of the E nitrous acid used in procuring these crystals need be nicely attended to; but the quantities obtained will be considerably diminished, if the boiling be continued after the vapours have disappeared.

It is concluded, that in this process the nitrous F acid does nothing more than afford vital air to combine with a vegetable basis existing in the sugar. The crystals are therefore called the acid of sugar, or saccharine acid. They have an exceedingly pungent taste, but excite an agreeable sensation on the tongue, when diluted with water. Vegetable blues, indigo excepted, are reddened by this acid, and it powerfully attacks and combines with alkalis, earths, and various metals, forming compounds that sufficiently distinguish it from every other acid. Boiling water dissolves its own weight of the crystals, but at 60° it will take up no more than half that quantity.

The saccharine acid effloresces in a heat greater G than 60°. It may be sublimed by fire, though not without alteration. Repeated sublimation destroys

it; during which a great quantity of aërial acid and inflammable air are extricated.

H The affinity of this acid to lime is greater than that of any other acid; the compound thus formed is insoluble in water, and can only be decomposed by fire. Hence the use of lime in causing sugar to crystallize. The native juice has a superabundance of acid that prevents crystallization; but this impediment is removed by the lime, which combining with it, is either carried off in the skum,

I or sinks to the bottom. Hence also the saccharine acid affords one of the nicest and most certain tests to discover lime in waters.

K Salt of sorrel consists of the vegetable alkali supersaturated with a peculiar acid. If the abundant acid be saturated with volatile alkali, and a nitrous solution of ponderous earth be added, decompositions and new combinations take place by double affinity. The nitrous acid seizes the volatile alkali, while the acid of sorrel, uniting with the ponderous earth, forms a compound, that, on account of its difficulty of solution, falls to the bottom. The sediment being washed, and placed in pure water, may be again decomposed by vitriolic acid, which forms marmor metallicum (175, N) with the earth. The disengaged acid of sorrel may be poured off. It is destructible by fire.

L If the juice of lemon be boiled to the consistence of syrup, the vapors that fly off are not at all acid, but the residue will not afford crystals.

A quantity

A quantity of pulveriſed chalk being added to ſaturation to boiling lemon-juice, combines with the diſengaged acid, and forms a compound, which, becauſe very ſparingly ſoluble in water, is precipitated. The ſaponaceous and mucilaginous matter of the juice remains in the ſupernatant fluid, and muſt be decanted from the precipitate, lukewarm water being repeatedly poured on this laſt till it comes off colourleſs. To decompoſe the precipitate, ſtrong oil of vitriol, equal in weight to the chalk made uſe of, but diluted with ten times its bulk of water, muſt be added. The mixture, after a few minutes boiling, will contain the vitriolic acid united to the lime in the form of gypſum (174, M), and the acid of lemon diſengaged in the water. Filtration or decantation will ſeparate the gypſum, and the acid of lemon may be obtained in cryſtals by evaporating the water. The cryſtallization, however, will not take place, if, for want of ſtrength, or a due quantity of vitriolic acid, there be left any lime in the ſolution. This may be known by adding a ſmall quantity of vitriolic acid to the ſolution when evaporated to the conſiſtence of thin ſyrup. If any precipitation takes place, more vitriolic acid muſt be added; and this laſt acid, if ſuperfluous in quantity, will be found in the reſiduum after cryſtallization. The acid of lemons, M
by digeſtion with ſpirit of wine and water, is converted into vinegar.

The ſaponaceous matter, decanted off after the N
addition of chalk to the lemon juice, may be con-

verted into acid of ſugar by treatment with nitrous o acid, but the acid of lemons cannot. It therefore appears, that lemons contain two acids, namely, the acid of lemons, diſengaged, and the acid of ſugar, in combination with oily or mucilaginous matter. Beſides this, a ſmall quantity of vegetable alkali is found, which ſhews itſelf by forming tartar, when the tartareous acid is dropped into lemon juice, and ſuffered to ſtand ſome days.

P The fragrant reſin, called benzoin, or benjamin, affords a concrete acid in the form of ſlender ſpiculæ, by ſublimation, either in cloſed veſſels, or by adapting a long paper-funnel to an earthen-pot, containing the benzoin in fuſion over the fire. This acid may be obtained in a ſtate of greater purity by careful boiling in powder with lime-water. The lime unites with the acid; and upon the addition of marine acid, the acid of benzoin which is ſcarcely ſoluble in cold water, falls to the bottom, while the muriated lime remains in ſolution. The acid of benzoin is deſtructible by heat, and when ſet on fire continues to burn with a bright yellow flame. It is readily ſoluble in ardent ſpirit, even in the cold.

Q Milk in a ſhort time grows ſour and thick during ſummer. By filtration and evaporation the curds may be ſeparated, and the whey is found to contain an eſſential ſalt, animal earth, or phoſphorated lime (197, s), ſugar of milk, a ſmall portion of ſalited vegetable alkali (193, x), and ſome mucilaginous matter. The whey being evaporated to one eighth, for the more effectual ſeparation

tion of the curd, and then ſtrained; the acid is to be ſaturated with lime. The phoſphorated lime is by this means precipitated, becauſe deprived of the exceſs of acid that before rendered it ſoluble, but the acid of milk, forming a ſoluble compound with the lime, ſtill remains ſuſpended: the former is therefore ſeparable by filtration. A ſolution of the acid of ſugar being added, ſeizes the lime, (204, a), and leaves the acid of milk again uncombined. Spirit of wine diſſolves this acid, but none of the other ſubſtances that remain in the whey. Evaporate the water, which would impede the action of the ſpirit by diluting it, and when the maſs is of the conſiſtence of honey, add the ſpirit. To this acid ſolution, after filtering, add pure water. Diſtillation will carry off the ſpirit, and leave in the retort pure acid of milk, diſſolved in water. The acid of milk yields no cryſtals, and when evaporated to dryneſs, deliqueſces again. It is deſtructible by fire, affording water, a weak acid, aerial acid, inflammable air, and coal. It exceeds vinegar in attractive power, and appears to be an incomplete vinegar, for want of a ſufficient quantity of ardent ſpirit For, if a ſmall proportion of ardent R
ſpirit be added to milk, the fermentation becomes more perfect, and vinegar is produced inſtead of this acid: and, in addition to this, the acid of milk, S
with the addition of ardent ſpirit, is converted into vinegar after a month's digeſtion.

By evaporating whey to the conſiſtence of ſyrup, T
a ſweet ſalt is obtained in cryſtals, called ſugar of

milk, which may be purified by ſubſequent ſolution and cryſtallization in water. In ſimple diſtillation its products are nearly the ſame as thoſe of ſugar; but when treated with nitrous acid (202, D) it affords fifteen and one-half parts in the hundred of ſaccharine acid, and about twenty-three and a half of another acid, only found in ſugar of milk. This laſt is in the form of a white powder. Sixty parts of boiling water diſſolve one of this acid, and, on cooling, about one-fourth part of the powder ſeparates in the form of very ſmall cryſtals. It is decompoſed by fire.

U When an ant-hill is ſtirred with a ſtick, the enraged inſects emit an acid, which may be perceived to be ſuch, both from its ſmell and taſte. Water or ardent ſpirit, in which they are agitated, becomes acid. In the proceſs with ſpirit, part of the acid ariſes in diſtillation with the ſpirit, but the greater part remains united with the phlegm in the retort. Freſh ants afford by diſtillation, without addition, near half their weight of acid. This, like all the acids of vegetables, is reſolvable by heat into aerial acid, and inflammable air.

V The acid of fat is obtained by repeated diſtillations of that ſubſtance.

W Pruſſian blue is a beautiful pigment, well known in the arts. It is produced by the union of calx of iron, with a peculiar acid. The proceſs for making it is as follows: Calcine equal parts of vegetable fixed alkali, and dried bullocks blood, till it ceaſes to emit either flame or ſmoke; then raiſe the fire

ſo

ſo as to give the maſs a low red heat. Throw this matter red-hot into as many quarts of water as there were pounds of the original mixture, and boil it for half an hour. Decant this liquid, and waſh the coaly reſidue with more water, till it comes off almoſt inſipid. Add this laſt water to the former, and boil the whole till it is again reduced to the former number of quarts. This is the lixivium x
ſanguinis, or pruſſian alkali; which, if added in proper quantity to a ſolution of iron, precipitates it partly in the form of a calx, and partly in the form of pruſſian blue. The marine acid being poured on this precipitate after edulcoration, diſſolves the calx, and leaves the pruſſian blue much purer. The method of combining the alkali with the pruſſian acid by calcination does not ſaturate the whole; for which reaſon part of the iron is thrown down in a calciform ſtate by that portion of the alkali which affords no pruſſian acid. But for v
chemical purpoſes the pruſſian ley is produced by boiling the alkali in pruſſian blue ready formed. The calx of iron is thus deprived of the pruſſian acid by the alkali, to which it has a greater affinity, and which it only quits when there is another acid preſent to unite with the alkali, as in the juſt mentioned inſtance of the ſolution of iron, where a double affinity takes place. The pruſſian alkali z
prepared in either way contains ſome iron. It can be had pure in no other way than by directly combining the pure pruſſian acid with a pure alkali.

A Pruſſian alkali, boiled in a retort, with weak vitriolic acid, emits the pruſſian acid in an aerial inflammable form, which may be abſorbed by water placed in the receiver. But as a portion of vitriolic acid comes over likewiſe, a ſecond diſtillation is neceſſary, with the addition of chalk. The vitriolic acid by this means forming gypſum, is detained, while the pruſſian acid paſſes over totally, before one-fourth of the water is diſtilled off. It is not therefore neceſſary to continue the diſtillation beyond that period.

B This acid is found to conſiſt of aerial acid, or its baſe azotic air and inflammable air. If equal parts of pulverized charcoal and vegetable alkali be made red-hot for a quarter of an hour in a crucible, and ſome ſal ammoniac, in ſmall pieces, be then briſkly ſtirred down into the maſs, the ammoniacal vapours will ſoon ceaſe. The ignited matter being thrown into water, affords a lixivium equal to the beſt that is made with blood.

C A ſolution of the ſaturated pruſſian alkali is a valuable precipitant for diſcovering iron in liquids; no other ſubſtance forming pruſſian blue.

CHAP.

CHAP. XIV.

OF FERMENTATION, AND THE AERIAL TARTAREOUS AND ACETOUS ACIDS.

When animal or vegetable ſubſtances have D their organization by any means ſo far impaired as to be no longer capable of performing the offices to which they were adapted, life ceaſes, and, unleſs the temperature and dryneſs of the ſurrounding medium be ſuch as either quickly to evaporate all the moiſture, and more volatile parts, or to fix the whole maſs by congelation, certain chemical proceſſes take place ſpontaneouſly, by means of which both the fluid and ſolid parts loſe their former arrangement and compoſition, at the ſame time that new combinations are formed. This act E of change is called fermentation, and is properly diſtinguiſhed into three ſtages, namely, the vinous or ſpirituous, the acetous, and the putrefactive fermentations.

It is generally underſtood, that the vinous fer- F mentation does not take place except where ſugar is preſent. The temperature moſt favourable to this fermentation is between thirty-ſix and ninety degrees; and the principal phenomena are theſe. The liquor becomes opake, and warm. Aerial acid riſes in minute bubbles from all parts. Mucilage is ſeparated: part ſubſiding to the bottom, and

and part being carried to the top by the fixed air. For a certain time theſe appearances increaſe, but afterwards diminiſh, and at length totally ceaſe; the fluid has then a pungent ſpirituous taſte, inſtead of the ſweetneſs it had before: its ſpecific gravity is conſiderably leſs: and it affords
H ardent ſpirit by diſtillation. The quantity of ardent ſpirit afforded by any fermented liquid is thought * to be in proportion to the diminution its ſpecific gravity undergoes by fermentation; whether this be true or no, has not yet been proved by experiments; but it is highly probable that an attention to this diminution will afford the manufacturer ſome method of eſtimating the ſtrength of beer, wine, and other liquors of the like nature.

I If the liquid in this ſtate be confined in cloſe veſſels, the fermentation continues, but with extreme ſlowneſs, an acid ſalt, called tartar, is depoſited, and the taſte of the liquor becomes milder and more agreeable.

K But if the fermentative proceſs be ſuffered to go on in open veſſels, more eſpecially if the temperature be raiſed to 90°, the ſecond ſtage, or acetous fermentation, comes on, air is emitted, the maſs grows warm, and mucilage is depoſited: the inteſtine motion at length ceaſes, and the liquid becomes clear: it is then vinegar, and may be had purer by diſtillation. Ardent ſpirit is no

* Richardſon on Brewing. London 1784.

longer

longer found in the liquid, but the vinegar, when ſufficiently concentrated, is itſelf inflammable.

L The crude vinegar may be kept in well cloſed veſſels; but if it be ſuffered to continue in the open veſſels, it gradually loſes its acidity, becomes viſcid and foul; emits air; ſtinks; volatile alkali flies off; an earthy ſediment is depoſited, and the remaining liquid is mere water. This is the third ſtage.

M The three ſtages of fermentation are never inverted in their order; that is to ſay, bodies that have paſſed the ſpirituous fermentation proceed to the acetous, and afterwards to the putrefactive proceſs, and cannot again be ſubjected to either, after paſſing it. Bodies that begin to be deſtroyed by the acetous fermentation proceed afterwards to the putrefactive, but are incapable of the vinous proceſs. And ſuch bodies as immediately putrefy cannot be made to undergo either of the other ſtages. N Some are of opinion that all vegetable or animal bodies, which are deſtroyed by ſpontaneous decompoſition, undergo the complete fermentative proceſs, but that the duration of one or more of the three ſtages is too ſhort to admit of their being properly diſtinguiſhed by obſervation.

O The aerial acid, or fixed air, is not only produced in fermentation, but is found in mines, caverns, or wells, or combined with water or earths (155, F, G. 162, B), and is beſides produced in various chemical proceſſes. Its ſpecific gravity being about one and a half time that of atmoſpherical air, cauſes it to lodge in the lower parts

of

of mines, where it is called choke damp. Its preſence is firſt obſerved by the extinction or imperfect burning of the lights of the miners. Pure fixed air is inſtantly fatal to animals that breathe
P it. The atmoſphere always contains ſome of this acid. Lime-water is the niceſt teſt for diſcovering it; the lime being rendered mild and precipitated (161, z). The immenſe quantity of this air, which is diſcharged by the vinous fermentation in breweries, affords opportunities of making the more obvious experiments in a very eaſy and ſtriking manner. For the ſtratum of air that covers the fermenting liquor is about ten or twelve inches deep, or more, accordingly as the horizontal ſection of the veſſel is higher above the ſurface of the liquor. Candles plunged in this body of air are inſtantly extinguiſhed, and the ſmoke remaining in the fixed air renders its ſurface viſible. Agitation throws it into waves. Water in a diſh, immerſed in the fixed air, and ſtirred briſkly, ſoon receives a ſtrong impregnation and lively taſte. This aerial fluid may be dipped into, and brought out in a jar, like any other fluid which is denſer than air, and does not readily mix with
Q it. Nothing can be more ſingular than the experiments made by pouring this air out of one veſſel into another. A candle becoming immediately extinct; an animal expiring in a few ſeconds, or an alkali cryſtallizing, when included in the veſſel that receives the fixed air at the ſame time that the ſight cannot perceive any thing that is poured.

The

The tartar that ſeparates from wines during the R
ſlow fermentation (212, 1), conſiſts of the vegetable alkali united to a peculiar acid. When purified by ſolution and cryſtallization, it is in commerce called cream of tartar. The acid in cream of tartar is more than ſufficient to ſaturate the alkali. At a moderate temperature, this ſalt requires about one hundred and fifty parts of water for its ſolution. This ſmall degree of ſolubility S
in tartar is wonderful, when it is conſidered that the acid, or the alkali ſingly, or even the neutral ſalt produced by perfect ſaturation of each, are very ſoluble.

The moſt convenient method of procuring the T
acid of tartar is, to add dry powdered chalk, by ſmall portions at a time, to one hundred parts of the ſalt diſſolved in boiling water, in a tin veſſel. About twenty-eight parts will be required before the effervescence ceaſes. At this period the liquid muſt be decanted, and will afford, by evaporation, fifty parts of the perfectly neutral ſalt, called ſoluble tartar, or tartarized vegetable alkali. The remaining powder conſiſts of tartarized lime, and weighs one hundred and three. On this waſhed powder let thirty parts of the ſtrongeſt vitriolic acid, firſt diluted with two hundred and ſeventy parts of water, be gradually poured. After twelve hours digeſtion, the mixture being frequently ſtirred with a wooden ſpatula, the clear liquor may be poured off, and conſiſts of the acid of tartar diſſolved in water. The vitriolic acid remains combined

with

with the lime in the form of gypſum. To diſcover whether the ſolution contains any vitriolic acid, a drop or two of a weak ſolution of ſugar of lead (which conſiſts of the calx of lead united to vinegar) may be added. A white ſediment falls of vitriolated lead, if that acid be preſent, but if not, of tartarized lead. It may be eaſily known by the effuſion of ſtrong vinegar on the precipitate, which of the two acids enter into its compoſition: for tartarized lead will diſappear by ſolution, but vitriolated lead will not. If the gypſeous reſidue contain any tartarized lime, it may be known by throwing a portion on hot coals, in which caſe the powder will grow black, and emit a ſmell of ſpirit of tartar. After filtration, and evaporation to the conſiſtence of ſyrup, the ſolution of tartareous acid affords cryſtals. The quantity of acid weighs thirty-four, and the evaporation is carried to dryneſs.

u Certain vegetables, that have not undergone fermentation, likewiſe contain the tartareous acid.

v By digeſtion with water and ardent ſpirit, this acid is converted into vinegar. In the fire it grows black, and affords a ſpongy coal, which contracts much, and grows white by ignition. By diſtillation it affords phlegm, ſcarcely acid, with ſome oil, and leaves an earthy reſidue, neither acid nor alkaline. It is not convertible into ſaccharine acid by treatment with nitrous acid.

w Crude vinegar may be rendered much ſtronger by expoſing it to the froſt. The water freezes

6 alone,

alone, and leaves the acid greatly concentrated; the water exceeding the acid that remains three or four times in quantity, or more, according to the intenſity of the cold. This proceſs renders the vinegar much leſs diſpoſed to the putrid fermentation. For this laſt purpoſe, however, it may x be of importance to obſerve, that boiling for a ſhort time, either prevents the putrid fermentation from coming on, or at leaſt retards it very much. Common vinegar, after ſuch boiling, will keep for ſeveral years *.

By diſtillation of crude vinegar the acid is ob- Y tained in that ſtate of purity in which it is called the acetous acid. It is then no longer ſuſceptible of the putrid fermentation. Like the other acids, it acts on alkalis, earths, and metals, with which it forms compounds diſtinctive of its own peculiar nature.

The acetous acid may be had very ſtrong by z diſtillation from cryſtals of verdigris, which is a ſalt conſiſting of copper combined with the acetous acid. It is then called radical vinegar.

* Scheele's Eſſays. I do not, however, find it anſwer with our common beer vinegars.

CHAP.

CHAP. XV.

OF THE ALKALIS.

A NEITHER the vegetable fixed alkali, nor
any of the salts containing it, are found in con-
siderable quantity in the mineral kingdom. It
B is procured by burning vegetable substances in
the open air, the salt being obtained from their
ashes by elixiviating them in water, and evapo-
rating the clear solution to dryness. The crude
or unrefined alkali, procured from wood-ashes, is
called pot-ash. It is imported from the northern
parts of Europe, where wood is cheap, and con-
tains about half its weight of common salt in the
state in which it is usually retailed in London.
An addition made doubtless with a view to frau-
C dulent profit. Pot-ash may be rendered purer by
solution in water and boiling. As the water eva-
porates, the common salt will crystallize and sub-
side, and the ley may be poured off at various
times. The greater part of any salts it may con-
tain are thus separated, after which the alkali
may be dried, and placed on an inclined plane of
glass, in a damp place. The purest part of the
alkali will attract the humidity of the air, and
run off in a liquid form into any receptacle placed
for that purpose.

D There is not, however, any method sufficiently
easy to render the fixed alkali of pot-ash pure enough

for nice chemical purpoſes, more eſpecially as this ſalt may be had, without much trouble, from nitre or tartar. If the fineſt priſmatic nitre be de- E
flagrated with charcoal (183, 1) the acid flies off, and the alkali remains in a mild ſtate, and very pure. For this purpoſe the nitre muſt be made red hot, in a crucible much larger than is ſufficient to contain it, and a ſmall quantity of groſsly powdered charcoal muſt be added. The inflammation inſtantly takes place, and continues till all the charcoal is conſumed. More coal muſt then be added, and the ſame repeated till no farther detonation happens; care being taken to raiſe the heat towards the end of the proceſs, ſo as to keep the alkali in fuſion, leſt it ſhould cover and protect the remaining nitre from the contact of the coal. This is called fixed nitre, though there is F
no difference between the ſpecimens of vegetable fixed alkali, when well prepared, whatever ſubject it may have been originally obtained from.

The vegetable alkali of tartar is very pure, and G
preferred by chemiſts to any other. The tartar is wrapped in wet brown paper, and the parcels are placed in beds or ſtrata, alternately with beds of charcoal in a furnace. The whole is then ſet on fire, and the fire continued till the blackening ſmoke ceaſes to riſe. If the heat be too intenſe, the alkali will melt, and mix with the impurities of the coal; but when the proceſs is well conducted, the parcels of ſalt may be taken out entire. By elixiviation in pure water, with filtra-

tion, evaporation, drying, and calcining, for a considerable time, with a low heat, the mild alkali is obtained very pure and white.

H Equal parts of tartar and grofsly powdered nitre, detonated together, afford a very good vegetable alkali; the acid of the tartar abounding with fufficient combuftible matter to decompofe the nitre. When fmall quantities of this are prepared at once, it generally happens that the decompofition is not entirely completed, fo that nitre and tartar remain mixed with the alkali; a circumftance of no confequence in the principal ufe to which this alkali is applied, namely, to bring earthy matters into fufion by fire. It is called white flux.

I For fome operations this mixture of nitre and tartar are made ufe of without previous detonation. In this ftate it is called crude flux.

K Two parts of tartar, and one of nitre being detonated together, produce an alkali abounding with tartar and coally matter. It is of ufe in fuch fufions as require the prefence of charcoal as in the fufion or reduction of metals. It is called black or reducing flux.

L The vegetable alkali attracts the moifture of the air, and does not cryftallize, unlefs combined with the aerial, or fome other acid.

M The mineral fixed alkali exifts in vaft quantities in the common falt of the ocean, or falt fprings, or in rock falt (189, H). It is fometimes found combined with the vitriolic acid in the form of Glauber's

ber's ſalt (174, K). On old walls it is found united to fixed air and water; in which ſtate it is collected at the ſurface of the earth in many places in Aſia and Africa. Borax likewiſe contains it (196, L). The mineral alkali has not been procured from the N
native ſalts containing it, the aerial excepted, by any proceſs ſufficiently cheap. It is obtained by O
the incineration of certain plants of the kali kind, growing near the ſea-ſide. The crude mineral alkali in commerce is called ſoda, or barillia. It contains ſeveral neutral ſalts in ſmall proportions. Repeated ſolution and cryſtallization in water are uſed to purify it, as it is more ſoluble than the other ſalts that contaminate it, and conſequently cryſtallizes laſt of all. For very nice purpoſes the pu- P
reſt common ſalt may be decompoſed by melting with calx of lead; the acid combining with the lead, and leaving the alkali diſengaged: or common ſalt Q
may be decompoſed by the addition of nitrous acid, which ſeizes the alkali, and forms quadrangular nitre. The nitre being deflagrated with charcoal, leaves the alkali diſengaged. In either caſe, if common ſalt or nitre remain in the alkali, they will be ſeparated by ſolution in water, and evaporation.

The mineral alkali is uſually combined with R
enough of fixed air to render it cryſtallizable. Its cryſtals contain above half their weight of water, which flies off by expoſure to the air, leaving the ſalt in a dry white powder. This alkali, when deprived of fixed air, will not cryſtallize, but, like

the vegetable alkali, attracts humidity from the air, and becomes fluid.

S The vegetable and mineral alkalis have a very great resemblance to each other in their properties, but the elective attraction of the former is, in general, the most powerful. Their combinations with acids have already been treated of. Their action on metals in the humid way is not considerable. The calces of several metals are soluble in alkalis by the dry method, as are likewise all the earths. Siliceous earths in particular, form, by fusion with alkalis, that beautiful product of human industry, glass. Caustic, or pure alkalis, unite with oily or fat substances, and form soap.

T The process for making glass is simple; but the practice is by no means easy. From one to two parts of alkali are mixed with two parts of vitrifiable earth, and the mixture calcined for a time in a heat not sufficient to convert it into glass. By this management great part of the more volatile matters, that might cause the melted mass to froth and swell, are dissipated. These calcined materials, called frit, are then melted into glass by a stronger heat; which, when formed into utensils, is gradually cooled in an oven. This is called annealing. The imperfections of glass are, opake spots, bubbles, veins, or a coloured tinge. Some glass will change, or be corroded by the action of the air, or chemical menstrua. Such, in general, has too much alkali, or has not been held long enough in

fusion.

fusion. Some will crack by small changes of temperature, by wiping, or by the slight scratches that an iron-instrument may make, or that may be produced by placing the utensil on a table where a particle or two of sand may casually lie. These faults commonly arise from a want of sufficient annealing, or the glass being suffered to grow too cold before it is carried to the annealing oven. The management of the heat is said to be of great importance in this art.

The art of making soap consists in depriving the alkali of the fixed air it may be combined with, and afterwards combining it with some oily substance, which, in the manufactories, is done by a gentle boiling. One part of quicklime, and two of soda, are boiled together for a short time, with twelve parts of water. The filtered lixivium is soap-lye, or a solution of caustic alkali, and may be concentrated by heat. If it be concentrated till its specific gravity is about 1.375, or, which is the same thing, till a phial that can contain an ounce of water will hold one ounce seven penny-weights and a half of the lye, the soap may be made without boiling. One part of this lye must be mixed with two of olive-oil in a glass or stone-ware vessel. The mixture being stirred from time to time with a wooden spatula, soon becomes thick and white, and in seven or eight days the combination is completed, and forms a very white and firm soap.

The lye in large manufactories is made no stronger than to float a new-laid egg, when the workmen begin

to form the mixture. To a part of the lye diluted they add an equal weight of oil, which is ſet on a gentle fire, and agitated. When the mixture begins to unite, the reſt of the lye is added, and the whole digeſted by a gentle heat till the ſoap is formed. If it be well made it is firm and white, not ſubject to become moiſt by expoſure to the air, and completely mixes with water, without exhibiting any drops of oil on the ſurface. Trial is made of it, and the requiſite alterations are obtained by the addition either of oil or alkali. At the end of the boiling common ſalt is thrown in. A twofold effect is hereby produced. The ſoap is ſeparated, becauſe not diffuſible in ſalt-water; and it is rendered harder by the complete ſeparation of vegetable alkali from it: for the vegetable alkali does not make a firm ſoap; and, as much of it as may be in the mixture, decompoſes a portion of the common ſalt by ſtronger affinity to its acid. The alkali of the decompoſed common ſalt, namely, the mineral, unites therefore with that portion of the oil which would otherwiſe have remained in combination with the vegetable alkali.

The cleanſing property of ſoap is well known, and is to be attributed to its alkali, which will render a ſmall portion of oily matter, beyond what it is already united to, diffuſible in water. Soap is eaſily prevented from mixing with water by any ſalt, except alkalis, and is therefore no contemptible teſt of the purity of natural waters (149, o).

Sal

Sal ammoniac, or falited volatile alkali, formerly Y imported from Egypt, is now made in large quantities in Britain. The volatile alkali is obtained in an impure liquid ftate by diftillation from foot or bones, or any other fubftance that affords it. To this the vitriolic acid is added. The vitriolic ammoniac (174, L) thus produced, is then decompofed by common falt, by double affinity; the vitriolic acid combining with the mineral alkali, and the marine acid with the volatile alkali. The liquor therefore contains Glauber's falt, and fal ammoniac, which are feparated by cryftallization, and the fal ammoniac is fublimed into cakes for fale. The cheapnefs of vitriolic acid and of common falt is the caufe why they are made ufe of inftead of the marine acid.

The volatile alkali cannot be had abfolutely Z difengaged from every other fubftance, except in the form of air. By diftillation of fal ammoniac with lime, a folution of pure volatile alkali in water comes over (144, D) which cannot be rendered dry for want of fufficient fixity in the falt. If chalk be ufed inftead of lime, the volatile alkali A receives more than its own weight of fixed air, and comes over in a concrete ftate much lefs pungent than in the other procefs, though not fufficiently neutralized to prevent its exhibiting its alkaline properties very ftrongly (160, W.)

Impure volatile alkali is purified by forming B fal ammoniac with the marine acid. Sal ammoniac becomes very pure by a few fublimations, and

the volatile alkali being recovered again by the procefs already defcribed, is found to be one and the fame falt, whatever may have been the fubject that originally afforded it.

C In the diftillation of the cauftic volatile alkali, (144, D) an aeriform fluid is extricated, which confifts of the alkali, either pure or elfe combined with too fmall a quantity of water (145, D) to admit of condenfation into the fluid ftate. It may be confined by quickfilver. With water it forms the cauftic volatile alkali, from which heat again expels it: with fixed air it forms the concrete volatile alkali; and with marine acid air (190, O) it forms common fal ammoniac. When the ftrong cauftic volatile alkali is diftilled, it is therefore neceffary to annex the pneumatic apparatus with water to receive the alkaline air (190, Q.)

D The electric fpark paffed through alkaline air produces an impure inflammable air three times the bulk of the alkaline. air, and when this is detonated with vital air, the refidue is azotic air. Hence the volatile alkali is fhewn, as well as from direct experiments of combination, to confift of inflammable air and azotic air.

E The properties of volatile and fixed alkalis refemble each other, but the elective attraction of the latter is moft prevalent. The volatile alkali has more direct action on metals and metalic calces than the fixed. In the dry way it cannot be exhibited. Cauftic volatile alkali combines with oils, though difficultly. The faponaceous liquid, called eau de luce, is a preparation of this fort.

CHAP.

CHAP. XVI.

OF MINES AND METALS IN GENERAL.

THE internal parts of the earth, as far as the F
excavations made by natural cauſes, or by the in-
duſtry of men, have given ſcope for obſervation,
exhibit ſtriking marks of the immenſe changes
that have been produced by the chemical action of
bodies on each other, during a courſe of ages far
preceding all human record. It ſeems probable, G
that the loftieſt mountains, which run in chains
through the great continents, and are compoſed
chiefly of granite, had their exiſtence as ſuch pre-
vious to that of the animals or vegetables on the
earth. The ſame remark applies likewiſe to moun- H
tains of limeſtone, or marble of a granular texture,
and is founded on the conſideration, that the re-
mains of thoſe organized ſubſtances are never found
in them, Other mountains, for the contrary reaſon, I
are evidently of poſterior formation. Such as have
their materials arranged in ſtrata or beds, ſeem to
have been formed by ſubſidence and cryſtallization
in water. The planes thus formed, appear, from a
variety of ſigns, to have been disjoined, broken,
and thrown up into heaps by earthquakes, or ſimi-
lar convulſions of nature. Volcanos, or the erup- K
tion of ſubterraneous fires, have alſo contributed
greatly to change the internal conſtruction and
external

L external appearance of the globe we inhabit. There is no country or climate where viſtiges of theſe awful phenomena are not plentifully to be met with. Volcanic hills are often pyramidical, with a plain, or hollow cavity at top, and have one or more ridges proceeding from thence as a center. Strata of lava, and other volcanic products, abound in the vicinity, moſtly beneath the ſurface, and are regularly diſpoſed ſo as to point out the ſource

M from which they formerly iſſued. Metallic bodies are moſtly found in the ſtratified mountains. The beds of theſe mountains being thrown up into an inclined poſition, appear to have been worn down by the long continued action of the atmoſpheric changes; ſo that ſtrata, which in lower grounds are too deep for the miners to arrive at, are here rendered acceſſible.

N Such metallic combinations as are found in nature are called ores. The metal is ſaid to be mineralized by the ſubſtance that is combined with it. It muſt, however, be obſerved, as an exception, that native metallic ſalts are not called ores.

O The chief mineralizers are ſulphur, arſenic, or its acid, and fixed air. Metals are alſo found native or uncombined; but ſparingly.

P There are entire mountains which conſiſt of iron ore: other ores form but an inconſiderable part of the mountain in which they are found. Some ores run parallel to the ſtony ſtrata, though very far from having that regularity of thickneſs

thoſe

thoſe ſtrata poſſeſs; others croſs the ſtrata in all directions. The laſt are called veins.

The ſtones wherein the ore is imbedded are call- Q
ed its matrix. Theſe are not peculiarly appropriated to any metal, but ſome ſtones more frequently accompany metals than others.

The art of extracting metals from ores in the R
ſmall way is called aſſaying or eſſaying. The term is alſo applied to the ſeparation of gold or ſilver from other metals, and procuring them alone. Ores may be aſſayed either by the dry or humid method. In the dry way the proceſs is conducted nearly in the ſame method as when the metals are extracted in the large furnaces, and, generally ſpeaking, diſcovers little more than the quantity of the metal contained in the ore. In the moiſt way, by ſkilful management, the quality and quantity of all the ingredients become known.

The proceſs by fire for obtaining metals from S
their ores in large qualities for commercial purpoſes, is called ſmelting.

The operations for ſeparating metals from ores T
are trituration, and waſhing in a ſtream of water, by which the lighter parts are carried off, while the heavier ſubſide. This is of ſervice when the metalliferous parts are conſiderably heavier than the reſt. Roaſting, by which ſulphur, water, arſenic, vitriolic acid, or other volatile and uſeleſs ſubſtances are diſſipated. Fuſion or ſmelting with ſuch a mixture of earths, or other matters as may facilitate the ſame, by which the ſuperfluous part of

the

the ore is ſcorified, or melted into a ſlag or glaſs, ſufficiently thin to allow the metalline particles to ſubſide to the bottom of the furnace in a reguline
u ſtate. In aſſays, combuſtible or coaly matters are uſed for fluxing the maſs, that the metal may be reduced by depriving it of the vital air it may be combined with; but in large works the fuel generally anſwers that purpoſe.

v It is obvious, that the trituration, waſhing and roaſting, are not in all caſes required; that in ſome caſes the roaſting muſt precede the trituration; and that the additions in the ſmelting require an attention to the ſuppoſed or known
w contents of the ore required to be fuſed. The previous examination of ores by the blow-pipe, (134, c) and more eſpecially the humid analyſis, are of great ſervice, by indicating the proper additions to be made in ſmelting.

x In the humid way the ore is finely powdered, and diſſolved in ſuch a menſtruum as is adapted to take up either the whole or ſome of the parts conjectured, or by blow-pipe experiments known, to enter into its compoſition. The undiſſolved reſidue, if any, is ſubjected to trials by other menſtruums. The parts in ſolution may be ſeparated by the addition of precipitating matters, or by evaporating the ſolvent to dryneſs. The properties and weight of the precipitates indicate both the quality and quantity of each ſubſtance contained in the ore. This method of aſſaying, though incomparably more exact than the other, is not yet much practiſed, becauſe the operations are ſlower, and require

an

an extensive application of the principles of the most enlightened chemistry *.

Metallic substances in their reguline state have a peculiar brilliancy and opacity (170, z.) Properties, undoubtedly owing to their great density, and their combustible nature. For the refractive power which bodies exert on light is found to be nearly as their densities (1. 262, A) excepting inflammable substances, and in these it is in a higher proportion. And, because the refraction and reflection of light arise from the same cause (1. 308, E) such bodies as refract most will also reflect the light most strongly. Opacity is a consequence of the reflection of light. White metals are very opake. Gold-leaf, which is about † the $\frac{1}{282000}$ part of an inch thick, transmits light of a beautiful green; but silver-leaf, which is about the $\frac{1}{100000}$ of an inch thick, is opake. Other metals have not been so much extended, and whether any of them are susceptible of it is not known. Y

Melted metals, like all other fluids, assume a symmetrical form in cooling (152, x.) The chrystals are larger the slower the transition from the fluid to the solid state; and the specific gravities of Z

* See Bergman's Opuscula, and Kirwan's Mineralogy.

† This is the thickness deduced from the weight and surface of a book of gold, when the metal is so fine as to have but three grains of alloy in the ounce, and the workman extraordinarily skilful. Finer gold cannot be wrought in this way, because it is too soft to expand over the irregularities of the gold-beater's skins.

some,

ſome, and, perhaps, all metals, are greatly affected in the ſame ſpecimen (17, w) from this circumſtance. Several metals are capable of having their cryſtals ſeparated by agitation or pounding, juſt at the time of congelation; and have then a powdery or granular form. Theſe, if ſtruck with a hammer immediately after congelation, are broken, and exhibit the regular arrangement of their internal parts. Lead affords a remarkable inſtance of this.

A Moſt metals will mix in all proportions with each other, though perhaps not uniformly, and may be afterwards ſeparated by proceſſes founded on the conſideration of their various fuſibility, ſolubility, or diſpoſition to be calcined.

B The ſpecific gravities of theſe metallic compounds is ſcarcely ever ſuch as would be mathematically deduced from their ſpecific gravities of the metals made uſe of, on the ſuppoſition of their junction by ſimple contact.

C The fuſibility of theſe compounds is likewiſe ſuch in ſeveral inſtances as would not be expected from the fuſibility of the ingredients. In particular, a mixture of eight parts biſmuth, five lead, and three tin, will melt even in a heat lower than is ſufficient to cauſe water to boil.

D The portion of baſer or leſs valuable metal that is mixed with gold or ſilver, is called alloy.

E The imperfect metals are calcined by heat with acceſs of air: during this proceſs they combine with the vital air of the atmoſphere. The calces of molybdena, arſenic, and wolfram, are capable of uniting

uniting with a larger portion of vital air, and then become acid. Whence it is conjectured, that all metallic calces are of an acid nature.

Metallic calces are revived by ſtrong heat in contact with combuſtible matter (152, w. 167, Q.) The black flux is very ſerviceable for this purpoſe; for, at the ſame time that its combuſtible part reduces the metal and its thin fuſion favours its ſubſidence, the alkali promotes the work, by combining with the fixed air commonly contained in the calx. F

A calx is heavier abſolutely, but not ſpecifically, than the regulus it was produced from. G

The calces of metals are not only capable of revivification, but ſome of them appear to combine with ſo large a proportion of carbon or coally matter by the vapour of ſpirit of wine being paſſed over them when melted, as actually to become converted into a ſpecies of charcoal. Copper in particular is converted into a charcoal of more than twenty-ſix times its former weight, which may be burned in vital but not in common air *. H

Metals are ſoluble in acids, but not in their reguline ſtate. Such acids as cannot calcine a metal expoſed to their action do not diſſolve it, though they will take up the calx. During the ſolution of metals phlogiſton eſcapes in the form of ſome kind of air that contains it. Metals too far calcined are not ſoluble. I

When a metal is diſſolved nearly to ſaturation in an acid, it will be precipitated in its reguline K

* Prieſtley, VI. 207—211.

form

form by the addition of another metal, provided the attraction of the dissolved calx for vital air of the metal last added, together with its attraction for the acid be less powerful than the same attractions on the part of the metal which is added. The order of the precipitations of metals by each other is the same in all acids; a circumstance which shews that the attractions of the metals to vital air are more concerned in the effect than those of the acids for the calces. The order is, zink, iron, manganese, cobalt, nickel, lead, tin, copper, bismuth, antimony, arsenic, mercury, silver, gold, platina: where any preceding in the list will precipitate any or all those which follow, but none of those that come before.

M Sulphur dissolves many metals, and the alkaline liver of sulphur dissolves them all except zink. For this reason, great care ought to be taken to roast sulphureous ores well, previous to assaying them with alkaline fluxes, as the sulphur, together with the alkali, forms this menstruum, and much of the regulus is retained.

N The imperfect metals are calcined by deflagration with nitre, and alkalise that salt in the same manner as any other phlogistic substance. Some of these, when sufficiently heated, burn, or are decomposed with flame, and most of them are rapidly burned by heating in vital air.

CHAP.

CHAP. XVII.

OF THE PERFECT METALS, GOLD, PLATINA, AND SILVER.

THE perfect metals, gold, platina, and silver, O
cannot be calcined in any sensible degree by mere heat, or deflagrated with nitre. When calcined by other methods, they may be reduced by heating, without the addition of any combustible matter.

Gold is a yellow metal of much greater specific P
gravity than any other, except platina (17, w); directly soluble in aqua regia (192, v), and the aerated marine acid, and precipitable from these in its metallic form, by the solution of vitriol of iron. Vitriolic acid, distilled from manganese, also dissolves it. It has all the metallic characters (170, z) in the most perfect degree. When in fusion, it has a sea-green colour, which is also the colour of gold leaf by transmitted light.

Gold is mostly, if not always, found in its me- Q
tallic state. Some sands afford gold by simple washing, the heavy metallic particles subsiding soonest. But when embodied in earths, or stones, these are pulverized and boiled with one tenth of their weight of mercury, together with water. The mercury, after a certain time, absorbs the gold, and may be separated by distillation. Or other-

wise by heating the sand red-hot, and quenching in water several times, for the purpose of cracking and dividing it, and then melting the whole into glass with twice its weight of the calx of lead, called litharge. Charcoal being added, revives the litharge into lead, which subsides to the bottom, carrying the gold with it. If the lead, thus separated from the sand, be again converted into litharge by calcination, the gold will remain separate at the bottom of the test (130, x).

R This last operation, called testing, or cupellation when performed in the small way, is one of the best methods of separating the imperfect from the perfect metals. The mass of metals to be cupelled is put, together with lead, into a small shallow crucible of burned bones, called a cupel, and fused with a considerable heat, with access of air. The lead continually vitrifies, and carries all the imperfect metals with it. No litharge is produced in the small way, because the glass of lead is imbibed by the porous cupel. During the cupellation, the scoriæ, running down on all sides from the metallic mass, produce an appearance called circulation, by which the operator judges that the process is going on well. When the metal is nearly pure, certain rainbow colours flash across the surface, which soon after appears very brilliant and clean. This is called the brightening, and shews that the cupellation is ended.

S If the cupelled mass contain more gold than silver, the gold may be dissolved by aqua regia, and

and the ſilver will remain in a powdery form. If the ſilver prevail, pure nitrous acid will diſſolve it, and leave the gold. It is found moſt advantageous to add pure ſilver, if required, to make the proportion of this metal to the gold as three to one. For in this caſe the quantity of ſilver is not ſo ſmall as to be protected by the gold from the action of the menſtruum, nor the gold ſo ſmall as to fall into powder, when deſerted by the ſilver. Theſe proceſſes are called parting.

If platina be ſuppoſed to be mixed with the T
gold, both may be diſſolved in aqua regia, and the gold will be precipitated alone on the addition of martial vitriol. No other metal is precipitable from its ſolvent by martial vitriol but gold. The iron of the vitriol thus uſed becomes more calcined than before.

The precipitate of gold from its ſolvent by a U
volatile alkali, or by a fixed alkali, if the volatile alkali be preſent in the menſtruum (192, v), has a wonderful power of detonating, with a moderate heat, the gold being at the ſame time revived. The force of this exploſion is not ſo great as that of gunpowder, if a judgment may be formed by burning it in a cloſed metallic veſſel; but is much greater, if attention be paid to the prodigious noiſe it makes, and the laceration of the metallic plate it is burned upon. Theſe contrary concluſions may be reconciled, either by ſuppoſing the force of aurum fulminans leſs than that of gunpowder, but that its velocity of expanſion is greater at the beginning;

or otherwiſe, by ſuppoſing its force to be greater, but that, when incloſed and in contact with red-hot metal, the powder is decompoſed in another way without exploſion. Experiment muſt, however, determine. From various experiments upon this dangerous compound, it is aſcertained that it conſiſts of gold calcined and united to volatile alkali, and that the exploſion is produced by the ſudden combuſtion of the inflammable air of the alkali, with the vital air of the calx, while the azotic air, or other principle of the alkali, is extricated in the elaſtic ſtate.

v Tin, either diſſolved in aqua regia, or in ſubſtance, added to a ſolution of gold, precipitates the gold in the form of a beautiful purple powder, called the purple powder of Caſſius, which is of uſe in enamels, as it gives a fine tinge to glaſs. The preparation of this powder, and the production of a clear ruby coloured glaſs, require peculiar management.

w Light diſtilled oils, and more particularly ether, take gold from its ſolvent, but no other metal. If the ether be left to evaporate, by imperfectly cloſing the phial, the gold falls in its metallic form, no longer ſoluble by the acid beneath. Ardent ſpirit, wine, or vinegar, mingle uniformly with ſolutions of gold, and ſeparate it alone. Theſe methods purify gold from all admixtures.

x Liver of ſulphur combines with gold in the dry way into a maſs, diſſolvable in water.

y The imaginary value of gold probably originated in

in its property of bearing the action of the air, and all other liquids commonly met with, without tarnishing or rusting; to which value, no doubt, its great and almost inimitable specific gravity has contributed.

The gold coins of Britain consist of eleven parts gold to one of copper. The alloy is required to give the necessary hardness.

Platina has been found hitherto only in the gold- z
mines in Peru. It comes over in the form of grains, intermixed with ferruginous sand and quartz. The grains that remain, after the most magnetical and earthy particles have been separated, are of a whiter colour than iron. These contain one third of their weight of iron, and have a specific gravity of 16 or 18. To purify A
it, it must be repeatedly boiled in marine acid, till no more iron is separated, then washed, and dissolved in aqua regia; to this the Prussian alkali is to be added till it ceases to precipitate any iron; the clear solution being decanted off, the addition of pure sal ammoniac will throw down the platina, which may be fused in the most violent heat of a furnace. No other metal is precipitable by sal ammoniac.

Platina thus purified, is by much the heaviest B
body in nature (17, w). It is very malleable, though considerably harder than either gold or silver. Its colour is not distinguishable from silver on the touchstone. When in the highest degree of purity it is not magnetical; but when its spe-

cific gravity is as low as 21.36, it ſtill contains iron ſufficient to render it ſuſceptible of the magnetic touch, and obedient to a ſtrong magnet *. It is ſoluble only in aqua regia, or the dephlogiſticated marine acid, and is not acted on by ſulphur. Mercury does not diſſolve it. It withſtands cupellation.

C Platina unites with moſt of the other metals, ſo as to compoſe a uniform compound.

D Silver is the whiteſt of all metals, ſoluble in moderately dilute nitrous acid, and in the vitriolic acid by the aſſiſtance of heat, but not directly in the marine acid, nor aqua regia. It is precipitable from either of the firſt mentioned acids by the addition of marine acid, which combines with its calx, and forms the nearly inſoluble compound called luna cornea. Its malleability, compared with that of gold (231, Y), is nearly in proportion to its ſpecific gravity.

E Native ſilver is found in a great variety of forms, and imbedded in various earths. Some of the maſſes have been found of the weight of ſixty pounds. The greateſt quantity of this metal comes from Peru.

F The ores of ſilver are very numerous. Sulphur, arſenic, marine acid, coal, iron, copper, antimony, are the ſubſtances that ſeverally or collectively, in greater or leſs proportions, enter into their compoſition.

* See the ſection on magnetiſm.

The

The ſolution of ſilver, in the nitrous acid, af- G
fords nitrated ſilver, or lunar nitre, in ſmall cryſtals. This ſalt detonates when heated with combuſtible matters, but fuſes in a moderate heat, without addition, into a dark coloured maſs, uſed by ſurgeons as a cauſtic, under the name of lapis infernalis.

Marine acid, or pure common ſalt, being added H
to a ſolution of ſilver, the ſilver falls down in combination with more than its weight of the marine acid. This compound melts in the fire, at a low red heat, and if caſt into thin plates, is ſemi-tranſparent, and ſomewhat flexible like horn; whence its name luna cornea. If carefully prepared, it proves clear, and is ſuppoſed to have given riſe to the notion of malleable glaſs. A greater heat does not expel the acid, but the whole concrete either riſes in fumes, or paſſes through the pores of the veſſel. As the marine acid throws down only ſilver, lead, and mercury, and the latter two of theſe are not preſent in ſilver that has paſſed the cupel (236, R) though a ſmall quantity of copper may elude the ſcorification in that proceſs, the ſilver which may be revived from luna cornea is purer than can be eaſily obtained by any other proceſs. It is reducible by tritura- I
tion with its own weight of fixed alkali and a little water, and afterwards melting the whole in a crucible, whoſe bottom is covered with mineral alkali, well preſſed, the maſs of luna cornea being alſo covered with the mineral alkali. This ma-

nagement is required in order that the reduction may take place before the volatilization comes on, which, in the usual method of reduction, would cause a considerable part of the silver to be lost.

K The property of forming a luna cornea, or scarcely soluble compound, with marine acid, affords a good test for detecting the presence of small quantities of that acid, or unmetallic salt containing it, in waters. For by dropping the solution of silver in nitrous acid into such waters, a cloud, of a curd-like appearance, will be immediately formed by the combination of the calx

L of silver with the marine acid, if present. This property also affords a method of purifying the nitrous acid (184, o).

M Silver is not corroded by the action of the atmosphere; but is very apt to tarnish and grow black by exposure to sulphureous vapors.

N Sulphur, and also the liver of sulphur, dissolve silver in the dry way.

The fulminating compound of volatile alkali with silver, exhibits one of the most astonishing instances of chemical detonation hitherto observed. Its properties were discovered by Berthollet *. Pure silver is dissolved in pale nitrous acid, and the calx precipitated by lime-water. After decantation of the fluid, the precipitate is exposed to the air for three days to dry, in which the inventor

* Journal de Phisique, June 1788.

thinks

thinks the preſence of light is requiſite. This dried calx being agitated or ſtirred in a ſolution of cauſtic volatile alkali, aſſumes the form of a black powder which, when ſeparated by decantation, and dried in the air, is the fulminating ſilver. The alkaline fluid likewiſe contains a portion of ſilver in ſolution which may be ſeparated by evaporation, and cooling ſo far as to afford cryſtals, which alſo poſſeſs the detonating property.

Gunpowder and fulminating gold are not to be compared with this new product, for the firſt requires ignition, and the latter a perceptible degree of heat to produce detonation. But the ſlighteſt agitation or contact is ſufficient to cauſe the ſilver to explode. When once obtained, it can no more be touched. Even the falling of a drop of water upon it produces the exploſion. No attempts can therefore be made to encloſe it in a veſſel. None but metallic veſſels can be uſed in the latter part of the proceſs. The ſafety of the operator will be endangered if any quantity exceeding a grain of ſilver be uſed, and even in this caſe it is proper that his face ſhould be defended by a maſk, with apertures for the eyes covered with ſtrong glaſs.

The theory of this detonation is the ſame as that of fulminating gold.

It is a valuable diſcovery of Mr. Kier *, that a mixture of ſtrong vitriolic acid with the nitrous acid or nitre is a powerful ſolvent of ſilver, though it

* Phil. Tranſ. 1780, p. 367.

ſcarcely

ſcarcely acts upon the metals. This is of conſiderable importance in the Birmingham manufacture where the ſilver in the cuttings of plated copper. is required to be ſeparated from this laſt metal. For this purpoſe the pieces of metal are put into a glazed earthen pan, and a compoſition of eight or ten pounds of oil of vitriol, with one pound of nitre, is poured upon them, ſtirred about, and the action of the fluid aſſiſted by a heat between 100° and 200° of Fahrenheit. When the liquor is nearly ſaturated, the ſilver is to be precipitated by common ſalt, which may be eaſily afterwards reduced, or otherwiſe the ſilver may be precipitated in its metallic ſtate, by adding to the ſolution a few of the pieces of copper and a ſufficient quantity of water, which enables the liquor to act on the copper. The theory of this effect ſtill remains to be inveſtigated.

Pure ſilver, like pure gold, is too ſoft to be uſed for ordinary purpoſes without alloy. In the Britiſh coinage fifteen parts of ſilver are alloyed with one of copper.

CHAP. XVIII.

OF THE IMPERFECT METALS; MERCURY, LEAD, COPPER, IRON, AND TIN.

Mercury or quickſilver is a metal of a bluiſh Q
white colour, not ſuſceptible of ruſt, or tarniſh,
by expoſure to the air. Its fuſibility is ſo great,
that it becomes fluid long before ice melts;
and its volatility is ſuch, that it is driven off
by actual ebullition, at a temperature (127, R)
which the greater part of the other metals ſuſ-
tain without melting. In its ſolid ſtate it is mal-
leable. Its ſpecific gravity (17, W) is greater
than any of the other metals, platina, gold, and
wolfram excepted. By a heat, nearly ſufficient to
cauſe it to riſe quickly in the vaporous form,
it is calcined, provided the acceſs of atmoſphe-
rical or pure air be allowed. This calx, impro- R
perly called percipitate per ſe, is of a red colour,
and reſumes its metallic form by mere increaſe
of heat, at the ſame time that it gives out pure or
vital air.

Native mercury is frequently found, but perhaps never free from metallic alloy. It is alſo found mineralized, in the form of precipitate per ſe, or combined with the vitriolic or marine acids, or with ſulphur. This laſt is called cinnabar. It is of various colours, from a yellowiſh to a deep

a deep red, and is very ponderous. In close
vessels it sublimes without any other alteration
than being deprived of its impurities; in open
u vessels, with sufficient heat, it is decomposed. The
mercury is obtained from it by distillation, with
the addition of some substance that will combine
with, and detain the sulphur; for which purpose
iron, in small pieces, is commonly made use of. But
if calcareous earth be mixed with or abound in the
v ore, no other addition is requisite. The paint call-
ed vermillion, is an artificial cinnabar, produced
by combining mercury with sulphur by trituration
and sublimation. One hundred parts of cinnabar
contain eighty of mercury, and twenty of sulphur.

w Mercury is judged to be pure when it is per-
fectly fluid, and runs in neat globules, without
any pellicle on its surface, or without soiling a
funnel of clean white paper, through which it may
be poured by a very small aperture at bottom. If
it leaves nothing behind after evaporation, its
x purity may be still more depended on. For pur-
poses where the utmost purity is required, the
mercury may be triturated with flowers of brim-
stone, till it disappears, by uniting with that sub-
stance in the form of a black powder, called
ethiops mineral; with this may be mixed twice
the quantity of quicklime or filings of iron, and
the whole being submitted to distillation, the mer-
y cury will rise, and pass into the receiver. Dust,
and other superficial impurities, are removed by
pressing mercury through a leathern bag.

The

The concentrated vitriolic acid, by boiling Y
combines with mercury into a white mass, which, by the effusion of a sufficient quantity of hot water, becomes of a citron colour. It is scarcely at all soluble in water, and is known in medicine by the name of turbith mineral.

Nitrous acid dissolves mercury very readily, and Z
affords, by crystallization, a salt called mercurial nitre. If this salt, which is white, be exposed to heat, it becomes yellow, then orange coloured, and, lastly, red, in which state it is found not to differ from precipitate per se (243, R. 182, G).

Vitriolic acid, added to a solution of mercury A
in the nitrous acid, seizes the metallic calx, and falls to the bottom; forming the same combination as would have been produced by the direct solution of mercury in the vitriolic acid (245, Y). The affusion of warm water converts it into turbith mineral.

The common marine acid does not dissolve B
mercury, though it readily unites with it when sufficiently calcined by other means. Thus, when mercury is calcined by nitrous acid, in which it is dissolved, the marine acid being added, immediately seizes the calx, and forms a salt of difficult solubility, which falls to the bottom. It is observable, C
in dissolving mercury in the nitrous acid, that the solution at the beginning is attended with the escape of nitrous air (185, R), but that the mercury continues to be dissolved after the emission of air has ceased. The latter portion is therefore taken up

in

in its metallic ſtate. If the marine acid be added
D to a ſolution of no greater quantity of mercury
in nitrous acid, than could be diſſolved with ef-
ferveſcence, the precipitate will be a ſalt of ſpar-
ing ſolubility in water, and highly corroſive, known
E by the name of corroſive ſublimate. But if the
nitrous acid be loaded with as much mercury
as it can take up, and marine acid be added,
the precipitate will be mild, and ſcarcely at all
ſoluble in water, and is then called mercurius dul-
cis, or calomel.

F Corroſive ſublimate has always, till lately, been
made by ſublimation. This is effected by a va-
riety of methods, all which tend to combine the
marine acid with the calx of mercury. If the
white ſaline maſs, produced by combining the
vitriolic acid with mercury (245, Y), be tritu-
rated with an equal weight of ſea-ſalt, and ex-
poſed to heat in a cucurbit (129, X) the vitriolic
acid quits the calx of mercury to combine with
the alkali of the ſalt, while the marine acid thus
diſengaged unites with the mercurial calx, and
forms the corroſive ſalt required. This is ſub-
limed by the heat, in a white maſs, cryſtallized in
the form of needles.

G Corroſive ſublimate, triturated with mercury,
abſorbs or unites with a quantity about two-thirds
of its own weight. Sublimation renders the union
more perfect, and affords the mercurius dulcis of
the ſhops.

H The aerated marine acid directly attacks and
calcines

calcines mercury, which it converts into corrosive sublimate.

Mercury combines with almost all metallic sub- I
stances, and communicates to them more or less of its fusibility. When these metallic mixtures contain enough of mercury to render them soft in a mean temperature, they are called amalgams.

Lead is a white metal of a considerably blue K
tinge, not subject to be much corroded by exposure to air or water, though the brightness of its surface, when cut or scraped, soon goes off. It is very soft and flexible; not very tenacious, and consequently incapable of being drawn into fine wire. Under the hammer it is easily extended into thin plates, but its properties have not induced workmen to subject it to the same trials as gold, silver, and copper, and therefore its comparative malleability is not known. Its specific gravity is considerable. On the fire it melts long before ignition, at about the 540th degree of Fahrenheit's thermometer, at which period it begins to be calcined, if respirable air be present. In a strong red heat it boils and emits fumes. If melted lead be poured into a box, previously rubbed with chalk, to prevent adhesion, and continually agitated, it will concrete into separate grains, of considerable use in a variety of mechanical operations; or if it be poured into a mould, and turned out at the instant of cooling, a blow with the hammer will break the

mass,

mass, and the symmetrical arrangement of the internal parts will be seen.

L The ores of lead are most commonly found among earths of the calcareous or ponderous kind. Calciform lead-ores are either transparent or opake spars, or pulverulent, or ochreous masses of a reddish or brown colour. They are reducible by fusion with combustible matters. Lead is also found mineralized by the vitriolic acid forming a white ponderous salt, soluble in water. Likewise combined with the phosphoric acid of a greenish colour. Sulphur is the usual mineralizer of lead. Of these the galena, or potters lead ore, is the most common. It is of a lead colour, but darker, and is for the most part formed in cubes of a moderate size, or grains of a cubical figure, with the cornets cut off; its texture being granular. When antimony enters into the composition, the texture is radiated or filamentous. There are also pyritous and red arsenical lead-ores, but the latter is very scarce. The sulphureous lead-ores contain silver. It is not indubitably established that native lead has ever been found.

M By calcination, lead is converted into a dusky powder called plumbum ustum; a longer continued heat, with access of air, renders it white, yellow, and after some days, of a bright red, called minium, or red lead. The heat for this purpose must not exceed a certain degree. A greater heat converts the calx, by degrees, into a yellow

yellow flaky calx, called litharge; and by a moderately strong fire, it runs into a yellow transparent glafs, which powerfully diffolves metallic calces (236, R); and unlefs combined with thefe, or earthy additions, corrodes and paffes through common crucibles. This glafs acts more strongly on filiceous than on argillaceous earths, and is a principal ingredient in fine white glafs.

Vitriolic acid, by boiling, combines with lead into a faline mafs. Nitrous acid unites with it into a cryftallizable falt. The vitriolic acid, added to a folution of lead in the nitrous acid, feizes the calx, and falls to the bottom, forming the fame compound as would have been produced by direct folution of lead. The marine acid in the fame manner carries down the lead, and forms a combination called plumbum corneum, which is more foluble in water than luna cornea (241, H). N

The marine acid acts directly on lead, by boiling. O

The acetous acid diffolves lead and its calces. White lead, or cerufe, is made by rolling leaden plate fpirally up, fo as to leave the fpace of an inch between each coil, and placing them vertically in earthen pots, at the bottom of which is fome good vinegar. The pots are to be covered and expofed for a length of time to a gentle heat in a fand bath, or by placing them in dung. The vapour of the vinegar attaches itfelf to the furface of the plates, and corrodes them, by that means reducing them into cerufe, which comes off in P

 flakes

flakes when the lead is uncoiled. The plates are thus treated repeatedly, till they are corroded through.

Q The acid in ceruſe is ſuperſaturated. By ſolution of this compound in acetous acid, a cryſtallizable ſalt, called ſugar of lead, is obtained, which is the ſame as would with leſs facility have been procured by diſſolving lead directly in that acid.

R Sulphur readily combines with lead, by the aſſiſtance of heat, and forms a compound, ſimilar to the ſulphureous lead ore.

S Oils and fats have a ſtrong action on lead and its calces. Litharge, or any of the other calces of lead are copiouſly and entirely ſoluble in oils by boiling, which are thereby rendered thicker, and more drying. Linſeed oil, thus impregnated with litharge, is much uſed by painters, under the name of drying oil. Many of the plaſters uſed in ſurgery have for their baſis oil thickened by boiling with calx of lead.

T Lead in its metallic ſtate unites with moſt metals. It may be ſeparated from copper by eliquation, or melting by a heat too low to fuſe the copper. It altogether rejects iron.

U Copper is a metal of a peculiar reddiſh brown colour, ſubject to tarniſh; it grows black by long expoſure to the air; and eaſily ruſts by moiſture. It is of very conſiderable hardneſs, tenacity, ductility, and malleability: and its elaſticity is greater than that of any metal, except iron. From this

laſt

last property, masses of this metal emit a loud and lasting sound when struck, and that, more especially, when of a proper figure (68, w). At a degree of heat, far below ignition, the surface of a piece of polished copper becomes covered with various ranges of prismatic colours, the red of each order being nearest the end which has been most heated; an effect, which must doubtless be attributed to calcination, the stratum of calx being thickest where the heat has been greatest, and gradually thinner and thinner towards the colder part (1, 280). A greater degree of heat calcines this metal more rapidly, so that it contracts thin powdery scales on its surface, which may be easily rubbed off, the flame of the fuel becoming at the same time of a beautiful green or bluish colour. In a strong white heat, greater than is necessary to melt gold or silver, it melts and exhibits a bluish green colour. v w

Copper is sometimes found native. Its ores are either calciform, of a red, blue, or green colour, or sulphureous, with more or less of iron, arsenic, or zink. It is also found mineralized by the vitriolic or marine acids (178, w). Copper is extracted from its ores by repeated fusions and roasting, by which the sulphur is driven off, and the baser metals scorified. Lead is an useful addition for depriving it of the last portions of sulphur. Silver is extracted from copper by eliquation (250, †) with lead, which carries the silver down with it. This process cannot however separate gold from x

 copper.

copper. When the quantity of gold is ſuſpected to be too ſmall to be advantageouſly recovered by teſting, (236, R) it may be extracted by pulverizing the ſulphurated copper, ſulphur being added if required, and grinding the maſs with mercury, which amalgamates with the gold (235, Q).

Y Vitriolic acid, highly concentrated and boiling, diſſolves copper, and by evaporation affords blue cryſtals (178, V) of vitriolated copper. By cementation of copper with ſulphur, part of the maſs becomes ſoluble in water, and affords the ſame ſalt.

Z Nitrous acid diſſolves copper with great violence, and forms a deliqueſcent ſalt. The ſolution is green, as are alſo the cryſtals. This ſalt, dried and placed in a heat not much greater than the hand can bear, takes fire.

A Marine acid likewiſe diſſolves this metal, and forms a deliqueſcent ſalt, which takes fire from a candle, and burns with a blue flame.

B Verdigris is made by ſtratifying copper plates with huſks of grapes after the juice has been preſſed out, the remaining acid forming this ſubſtance
C by corroding the metal. Verdigris diſſolved in diſtilled vinegar becomes completely ſaturated with acid, and when cryſtallized, is improperly called diſtilled verdigris.

D Copper may be deprived of any acid by diſtil-
E lation, without any intermediate ſubſtance. The acetous acid thus recovered from cryſtals of verdigris, is called radical vinegar (217, 2).

When

When copper is ſeparated from any acid by the F
addition of an alkali, in greater quantity than is ſufficient for the purpoſe, the alkali diſſolves part of the calx, and gives the liquor a blue colour.

Cauſtic volatile alkali diſſolves copper if the G
acceſs of reſpirable air be permitted. The ſolution is of a fine blue, and yields on evaporation, a ſaline maſs of the ſame colour. It is obſervable that the alkaline liquid remains colourleſs while the air is prevented from communicating with its ſurface, but that the blue colour extends gradually from the ſurface downwards, when the veſſel is opened. A circumſtance well explained from the conſideration that the air combines with the copper and renders it ſoluble.

Neutral ſalts, and alſo oils and fat ſubſtances, H
have a conſiderable action on copper.

Copper mixes with the other metals. The I
compoſitions moſt generally in uſe, in which copper enters as the principal part, are braſs and bell-metal.

Braſs is compoſed of copper and zink. Ac- K
cording to the proportion of zink, the braſs is of a yellower and paler colour than copper, and when the zink greatly abounds it is white. Braſs is very ductile and malleable when cold, but brittle when hot. It is harder, more ſonorous, and not ſo liable to ruſt as pure copper; and is alſo more fuſible, and leſs ſubject to ſcorify in a moderate heat. Theſe properties, added to the beauty of its co-

lour, render it a very valuable material in the arts.

L The fineſt braſs is not made by the fuſion of copper and zink, but by the cementation of granulated copper with pulverized calamine and charcoal. The calamine, which is an ore containing zink in a calcined ſtate, parts with its zink in the form of vapour when revived by the charcoal; and this volatile ſemi-metal combines with the copper. The proceſs laſts eight or ten hours, or even ſome days, according to the quality of the calamine, at the end of which, by an increaſe of heat for a ſhort time, the braſs is fuſed into a maſs at the bottom of the crucible. The quantity of zink in good braſs, may be about one third.

M Bell-metal is compoſed of copper alloyed with tin. According to the proportion of tin the compound becomes paler than copper, and when the tin amounts to one third of the maſs, it becomes of a very beautiful yellowiſh white. It is remarkable that zink, which is ſcarcely at all malleable, ſhould unite with copper into the malleable compound braſs; and on the contrary, the two malleable metals, tin and copper, compoſe bell-metal, which is ſo brittle, that it may be reduced to powder. The ſpecific gravity of bell-metal is a circumſtance equally ſingular; for in moſt proportions of the mixture it is about as heavy as the heavieſt of the two metals, copper; and when the tin is about one third, its denſity is actually greater than

than that of copper*. The extreme hardneſs and ſonorouſneſs of this compound, together with its being leſs ſubject to alter by expoſure to the viciſſitudes of the air, than any other cheap metallic compound poſſeſſing the ſame properties, have recommended it in the fabrication of various utenſils and articles; as cannon, bells, ſtatues, &c. in the compoſition of which, other metals, however, are mixed in various proportions, according to the fancy or the experience of the artiſt.

The attention of the philoſopher is more particularly directed to the mixture of copper and tin, on account of its being the ſubſtance of which the ſpeculums of reflecting teleſcopes are made. For this purpoſe there is required a metal capable of an exquiſite poliſh, hard enough to receive and retain a figure accurately ſuited to the regular reflection of light, and not ſubject to loſe its poliſh or figure by the action of air and the vapours uſually floating therein. Such a compoſition, it muſt be confeſſed, is ſtill a deſideratum; but the experiments and practice of the beſt artiſts ſhew, that pure copper alloyed with pure tin, affords a metal equal at leaſt to moſt of the leſs ſimple mixtures given in books. As to the proportions, it is found that a ſmall addition of tin renders the colour of copper whiter, and at the ſame time hardens it conſiderably. Theſe effects are more and more prevalent while the doſe of tin increaſes as far as a certain point. Fourteen ounces and a half of tin to

* Lewis on Newman, 1, 97.

two pounds of copper, is a good compoſition for
O mirrors. One third part tin produces a whiter colour, but is too hard to be worked in the uſual
P methods of grinding. If the doſe of tin be greatly increaſed, a ſofter metal of a bluiſh white colour is obtained, which bears and retains a good poliſh and figure, but does not ſeem equal to the yellowiſh white. Some care and attention are required in caſting mirrors, that they may not prove full of microſcopic pores by the intermixture of calx. For this metal is eaſily reduced to a calx, and burns with a purple flame in a ſtrong red heat.
Q To prevent this, the copper muſt firſt be fuſed in a melting-pot, larger than ſufficient to contain the whole, and whoſe upper part is filled with pulverized charcoal, and the tin afterwards added; and when the mixture is completed, the whole muſt be ſuffered to cool, nearly to concretion, before it is poured out. Or, which is ſtill better, it may be poured out and again melted with a low heat, ſuch as is merely ſufficient for the purpoſe. Among various pieces caſt out of the ſame fuſion, the latter proved always cleaner, better adapted to the mould, and of a more uniform texture when poliſhed. The quantity of about one fiftieth part of arſenic added at the laſt fuſion greatly improves the denſity of the metal.

R Iron is a metal of a bluiſh white colour, more or leſs dark in various ſpecimens, ſubject to ruſt by expoſure to air and moiſture. Its tenacity, ductility, and malleability are very great; and it

exceeds

exceeds every other metal in elasticity and hardness. The appearance of prismatic colours (251, v) on its polished surface takes place long before ignition. It may be ignited by a quick succession of blows with a hammer. Struck with a flint it emits decrepitating ignited particles, such as can be obtained from no other metal by the same means. It is easily calcined by fire, but requires a most intense heat to fuse it when pure. During its decomposition by heat, it exhibits stronger marks of combustion than any other entire metal. It is even said *, that the blast of bellows will maintain its heat after it has been strongly ignited and taken out of the fire; and it is certain that the end of an iron wire being made red hot and dipped in a jar of vital air, will be entirely consumed by the successive combustion of its parts. Very fine shavings are consumed even in the common air. In a white heat, iron appears as if covered with a kind of varnish, and in this state two pieces applied together will adhere and may be perfectly united by forging. This operation, peculiar to iron, is called welding. Iron is thought to be the only substance in nature that has the property of becoming magnetical. Such other bodies as have that property, possess it in a very slight degree, and it may arise from iron contained in them, as far as experiments have yet unequivocally shewn.

Iron is more abundant and more universally diffused than any other metallic body. Few sands,

* By Dr. Hooke.

clays,

clays, ſtones, or waters of rivers, ſprings, rain, or ſnow are perfectly free from it. The parts of animal and vegetable ſubſtances have been alſo obſerved to contain it. Native malleable iron has been found, though rarely. Its ores are either purely calciform, as in ochres and hæmatites; or the calces are mixed chiefly with earths, as in ſpars, jaſper, boles, baſaltes, micas, &c.; or the iron is mineralized with ſulphur, as in pyrites, (171, c) with arſenic in the white pyrites, or with both; with bitumen in the coal ore; or combined with the vitriolic acid in native vitriol or vitriolic waters.

T The ores of iron, after roaſting, are ſmelted in furnaces of various magnitudes and forms. Some are thirty feet in height, their internal ſhape being nearly the fruſtum of a cone, whoſe larger baſe is uppermoſt. Near the bottom is an aperture, for the inſertion of the pipe of large bellows, worked by water, or of other machines for producing a current of air, and alſo holes to be occaſionally opened to permit the ſcoria and the metal to flow out, as the proceſs may require. Charcoal or coke, with lighted bruſhwood, is firſt thrown in, and when the whole inſide of the furnace has acquired a ſtrong ignition, the ore is thrown in by ſmall quantities at a time, with more of the fuel, and commonly a portion of lime ſtone, as a flux. The ore gradually ſubſides into the hotteſt part of the furnace, where it becomes fuſed, and the metallic particles revived by the coal paſs through the ſcoria,

ſcoria, and poſſeſs the lower place. The quantity of fuel, the additions, and the heat muſt be regulated in order to obtain iron of a good quality; and this quality muſt likewiſe, in the firſt product, be neceſſarily different, according to the nature of the parts that compoſe the ore.

The beſt caſt iron, or iron as much freed from heterogeneous matters as the uſual proceſs of ſmelting can effect it, is not at all malleable, and ſo hard, as perfectly to withſtand the file. If this be kept in fuſion for a conſiderable time, it boils, and much ſcoria is ſeparated; and by repeated blows of a large hammer on the maſs, when nearly at the melting heat, more extraneous matter is forced out, and it is rendered malleable. In this ſtate it is much ſofter than before, and of a fibrous texture.

Steel is iron in an intermediate ſtate between caſt iron and iron which is ſoft, tough, and malleable. The iron run from ſome German ores is found to be a good ſteel, when forged only to a certain point. But ſteel is uſually made by cementation from the beſt forged iron with matters chiefly of the inflammable kind. Two parts of pounded charcoal and one of wood aſhes is eſteemed a good cement. The iron bars are bedded ſeparately, or apart from each other, in this cement, in a cloſed crucible, and kept in an equal red heat for eight or ten hours, at the end of which time they are found to be converted into ſteel. If the cementation be continued too long, the ſteel is brought to a ſtate reſembling caſt iron, being

rendered

rendered exceſſively brittle, incapable of being weld-ed, and apt to crack and fly in forging: but on the contrary, cementation with abſorbent earths or ſimple ignition long continued, reduces ſteel to the ſtate of forged iron.

x It is a valuable property of ſteel, that though it is ſufficiently ſoft when gradually cooled, to be formed without difficulty into various tools and utenſils, yet it may be afterwards rendered more or leſs hard, even to an extreme degree, by ſimply plunging it, when heated, into cold water. The hardneſs produced, is greater in proportion as the ſteel is hotter and the water colder. The colours that appear on the ſurface of ſteel ſlowly heated, are yellowiſh white, yellow, gold colour, purple, violet, deep blue, yellowiſh white, after which the ignition takes place. Theſe ſigns direct the artiſt in re-ducing or tempering its hardneſs. Ignited ſteel quenched in water, proves exceſſively hard and brittle, but it may be reduced to the required degree of ſoftneſs by heating it till it exhibits a known co-lour. Soft ſteel has a greater ſpecific gravity than that which is hardened.

y Crude iron, by cementation with animal aſhes, may be brought up into a ſtate reſembling ſteel, and ca-pable of being hardened by immerſion in water; and a farther continuation of this proceſs carries it be-yond that point, ſo that it reſembles forged iron. But this management is much leſs effectual than forging, probably becauſe the impurities of the crude iron are not removed by it.

Tools

Tools and other articles wrought in forged iron, are often cemented with a compoſition of burned leather, horns, or the like ſubſtances for a ſhort time, by which a very thin ſtratum of the external part is converted into ſteel, and is hardened by immerſion in water. This is called caſe-hardening.

The chief differences in iron appear to depend A
on the preſence or abſence of plumbago (169, v). When caſt iron is diſſolved in the vitriolic acid, a reſidue remains untouched, which is found to conſiſt chiefly of plumbago, inflammable air being at the ſame time extricated (179, A). Steel in the ſame circumſtances affords leſs plumbago and more inflammable air. Tough, malleable iron, ſimilarly treated, leaves ſcarcely any reſidue, but gives out more inflammable air than either of the other kinds of iron. It is therefore ſeen that caſt iron conſiſts of the metal combined with plumbago, and perhaps calcined to ſuch a degree as may be probably neceſſary (233, I) in order to be capable of ſuch an union. Steel is a more perfect iron, nearly as malleable in its ſoft ſtate as forged iron; but in its hard ſtate as brittle as the crude caſt iron. Pure forged iron is the metal itſelf alone.

The iron obtained from various ores, or by va- C
rious proceſſes, is found to differ in its qualities in ſeveral other reſpects, the cauſes of which have not yet been ſufficiently examined. In particular, the iron of certain ores, eſpecially if the fuſion in the ſmelting furnace has not been continued a ſufficient time, has the quality of breaking in

pieces

pieces under the hammer when ignited. This is called red-ſhort iron, and is ſuppoſed to contain arſenic.

D Such iron as contains the phoſphoric acid, is malleable when ignited and brittle when cold. This is called cold-ſhort iron.

E The vitriolic acid diſſolves iron readily, and forms vitriol (178, U). The metal of this ſalt while in ſolution is farther calcined by the contact of air, and is by that means rendered leſs ſoluble in the acid (233, I). A quantity of ochreous matter or calx, therefore, gradually falls to the bottom in that caſe, and the liquor, as well as the cryſtals, obtained from it by evaporation, are paler.

F Dilute nitrous acid diſſolves iron and forms a ſaline combination incapable of cryſtallizing. Strong nitrous acid corrodes and calcines a conſiderable quantity of iron, which falls to the bottom.

G Marine acid likewiſe diſſolves iron, and forms an incryſtallizable compound.

H The Pruſſian acid precipitates iron from its ſolutions in the form of Pruſſian blue (208, W).

I Galls and other aſtringent vegetables precipitate iron from its ſolution in the form of a deep blue or purple fecula, of ſo intenſe a colour as to appear black. The infuſion of galls, and alſo the Pruſſian alkali, are teſts of the preſence of iron by virtue of the precipitates they throw down. Acids diſſolve the black precipitate cauſed by

K galls: alkalis convert it into a brown ochre. A good

good and durable black ink may be made by the following directions: To two pints of water add three ounces of the dark coloured rough ſkinned Aleppo galls in groſs powder, and of raſped logwood, green vitriol, and gum arabic, each an ounce. This mixture is to be put into a convenient veſſel, and well ſhaken four or five times a day, for ten or twelve days, at the end of which time it will be fit for uſe; though it will improve by remaining longer on the ingredients. Vinegar inſtead of water makes a deeper coloured ink; but its action on pens ſoon ſpoils them.

Iron has a ſtrong attraction to ſulphur. If a L
bar of iron be ſtrongly ignited and a roll of ſulphur be applied to the heated end, it will combine with the iron and form a more fuſible maſs, which will drop down. A veſſel of water ought to be placed beneath, for the purpoſe of receiving and extinguiſhing it, as the fumes would otherwiſe be inconvenient to the operator.

If a mixture of five or ſix pounds of filings of M
iron be moiſtened with a ſufficient quantity of water to form a paſte, it will in a certain time ſwell, become hot, melt, fume, and even take fire. The reſiduum furniſhes martial vitriol. This proceſs is ſimilar to the decompoſition of the martial pyrites (171, D; 150, T; 124, N). The water ſeems to be neceſſary to enable the acid to act on the iron.

Iron may be allayed with all metals, except lead N
and mercury. A coating of tin defends it from

ruſting

rusting by the action of the air and other solvents, and is accordingly much used.

o Tin is a metal of a yellowish white colour, not subject to rust, though its scraped or polished surface soon loses its brightness. It is not quite so soft as lead, has not much tenacity, and is the least heavy of any of the intire metals. Under the hammer it is beat into leaves of about the thousandth part of an inch in thickness, and might easily be beaten to less than half that thickness, if the purposes of trade required it. Long before ignition, it melts at about the 410th degree of Fahrenheit's thermometer, and by continuance of the heat, slowly calcines into a white powder. Tin, like lead, is brittle when heated almost to fusion, and being broken by the blow of a hammer, exhibits a grained or fibrous texture. It may also be granulated by agitation, at the time of its passing from a fluid to a solid state (247, K). Its calx resists fusion more than that of any other metal, and from that property it is useful to form an opake white enamel, when mixed with pure glass in fusion.

P The largest quantities of tin are found in the county of Cornwall in England. It is also found in Saxony, Bohemia, and the peninsula of Malacca in the East Indies; but rarely in any other countries in sufficient quantities to pay the charges of working. Native tin is seldom met with. The ores of tin are almost always calces of that metal in a crystallized form, bedded commonly in a sili-

ceous matrix. Such are the white tin spar, the opake brown or black ore, the garnet ore, which abounds with iron, and the tin stone. These are all much heavier than any unmetallic substance. Tin has been found in Siberia, united with sulphur.

Tin ores, when impure, are cleansed from heterogeneous particles by pounding and washing (229, T). A slight previous roasting renders the stony admixtures more friable; and when arsenic is contained in the matrix, it is driven off by a strong heat, continued for a short time, the ore being frequently stirred to prevent its fusion. In the smelting, care is taken to add a larger quantity of charcoal than is commonly used in other fusions; and, to avoid a greater heat than is necessary to reduce the ore, in order that the loss of metal, which would otherwise happen by calcination, may be prevented as much as possible. Q

Concentrated vitriolic acid dissolves tin in a boiling heat. During the solution, vitriolic acid air escapes, and sulphur is formed in dark coloured particles, which are said to sublime in their proper form * in the neck of the retort. R

Nitrous acid acts very powerfully on tin. To obtain a perfect solution, the metal must be added a very little at a time, and all heat avoided; for if much tin be put in at once, the corrosion takes place with great rapidity and heat, and the metal falls to the bottom in the form of S

* Neumann.

a white calx, insoluble in acids (233. 1), and of difficult reduction. The salt, formed by the union of tin with the nitrous acid, burns and sparkles in a red heat.

T If crystals of cupreous nitre (252, z) be grossly pulverized, moistened, and rolled up in tin-foil, the salt deliquesces, and the nitrous acid begins to act on the tin with heat, nitrous fumes are emitted, the cupreous nitre takes fire, and burns likewise the newly formed portion of nitrated tin.

U Marine acid dissolves tin with the assistance of heat, and affords crystals by evaporation. If corrosive sublimate be added to tin, divided by previous amalgamation with mercury, the marine acid combines with the tin, and comes over by distillation, in the form of a strong smoking liquid, which, if diluted with water, grows opake, and deposits calx of tin.

V Aqua regia dissolves tin directly, and when loaded with that metal, has a gelatinous appearance. This solution is used by dyers for heightening the colours of cochineal, gum-lac, and some other red tinctures, from a crimson to a bright scarlet, in the dying of woolens.

W Tin combines with sulphur by fusion, and forms

X a brittle mass less fusible than pure tin. If the amalgam of tin, with half its weight of mercury, be set to sublime with sulphur and sal ammoniac, each equal in weight to the mercury, the whole being previously well mixed in powder, a sparkling gold coloured substance is obtained, which consists

consists of tin and sulphur, and is called aurum musivum. The process is thus explained: as the heat increases, the tin, by greater affinity, unites with the marine acid of the sal-ammoniac, and sets its volatile alkali at liberty, which flies off, together with a portion of the sulphur, in the form of an hepar. The salited tin rises by sublimation, and is found adhering to the sides of the vessel. The mercury, which was only added to divide the tin, combines with part of the sulphur, and forms cinnabar, which also sublimes. And the remaining sulphur, with the remaining tin, forms the aurum musivum, which occupies the lower part of the vessel. It is used as a pigment.

Tin unites with all the metals. Clean iron plates, dipped in melted tin, become covered with a thin coating of that metal, and form a very useful material for making wholesome kitchen utensils, and other articles. In performing this business it is found necessary, either to dip the clean iron previously in a solution of sal-ammoniac, or to keep the surface of the tin covered with fat and pitch, in order that the apposition of the two metals may not be prevented by the calces that the contact of air might form on their surfaces. These plates, which possess the cleanliness of tin, added to the rigidity of iron, are much used. In England they are called tin plates.

Pewter is a compound metal, whose basis is tin. The best pewter consists of tin allayed with a quantity not exceeding one twentieth of copper, or

other metallic bodies, as the experience of the workman has ſhewn to be moſt conducive to the improvement of its hardneſs and colour. The inferior ſorts of pewter contain much lead, have a bluiſh colour, and are ſoft.

A Uſeful compounds are made with tin, and a large proportion of copper (254, M).

CHAP. XIX.

OF THE SEMI-METALS, BISMUTH, NICKEL, REGULUS OF ARSENIC, COBALT, ZINK, REGULUS OF ANTIMONY, OF MANGANESE, OF WOLFRAM, AND OF MOLYBDENA.

B BISMUTH is a yellowiſh or reddiſh white ſemi-metal, little ſubject to change in the air. It is ſomewhat harder than lead, and ſcarcely, if at all, malleable, being eaſily broken, and even reduced to powder by the hammer. The internal face, when broken, appears compoſed of large ſhining plates, diſpoſed in a variety of poſitions. It melts at the 460th degree of Fahrenheit. Thin pieces are conſiderably ſonorous.

C This ſemi-metal is often found native. Its ores are either calciform or ſulphureous.

D Biſmuth is ſcarcely ſoluble in the vitriolic acid, and ſtill leſs in the marine. Nitrous acid, or aqua regia, diſſolves it. The addition of pure water precipitates

precipitates its calx, and is the criterion by which bismuth is distinguished and purified from all other metals. This white calx, called magistery of bismuth, or Spanish white, is used as a paint for the complexion, which however it gradually impairs.

Most metallic matters unite with bismuth, and are rendered more fusible by the addition. It is used in making pewter, printers types, solder, &c. The great fusibility of the mixture of bismuth, tin, and lead (232, c), renders it of use in making collars for the axles of some mechanical instruments to run in. E

Nickel is a semi-metal of a reddish white colour, of great hardness, scarcely yielding to the file, and of an uniform texture. It is very difficult to purify it, and is supposed, even when as pure as it has hitherto been obtained, to contain iron, as it is magnetical. It is malleable, and scarcely more fusible than pure iron. F

The vitriolic and marine acids do not easily attack this semi-metal. The nitrous acid and aqua regia dissolve it readily. Its solutions are deep green. G

Regulus of arsenic is of a bright yellowish white colour, subject to tarnish, and become black by exposure to air; very brittle, and of a lamellar texture. By heat it sublimes partly in the form of calx, and partly unaltered. The fumes have an offensive smell, resembling garlick, and are said to be dangerous. H

I The arsenic met with in commerce is brought chiefly from the cobalt works in Saxony, for making zaffre and smalt. The arsenic contained in great quantity in cobalt ores, is driven off by long torrefaction. These fumes pass into and adhere to the sides of a very long chimney, constructed for that purpose. Arsenic is a calx of the regulus, and contains no fixed air. It is so far in a saline state as to be soluble in eighty times its weight of water.

K The regulus is obtained from this calx, either by quickly fusing it together with twice its weight of soft soap and an equal quantity of mineral alkali, pouring it out, when fused, into an hot iron cone; or by mixing it, in powder, with oil, and distilling the whole gradually to dryness. The regulus sublimes towards the end. This process is too offensive to be made but in the open air.

L White arsenic previously divided by solution in boiling marine acid, is so far calcined by repeatedly pouring nitrous acid on it, and distilling it off, and at last raising the heat to ignition, that it becomes an acid, in the form of a concrete white mass, very soluble in water, and possessing peculiar properties. This is the arsenical acid.

M The aerated marine acid (191, s, T) likewise affords vital air to the arsenical calx, and produces the arsenical acid *.

* These processes are amply described in Scheele's Chemical Essays. London, 1786.

The

The vitriolic acid dissolves the regulus of arsenic by boiling. The marine acid and aqua regia also dissolve it by heat. Nitrous acid calcines it (271, L). N

Arsenic in any form is a strong poison. O

Cobalt is a semi-metal of a bluish grey colour, of considerable hardness, and very brittle. When well purified it is nearly as infusible as iron. Its ores are either calciform, or it is mineralized with the vitriolic or arsenical acid. They mostly abound with arsenic, and contain bismuth, iron, or other metallic matters. P

These ores have not been found in plenty, or at least worked to advantage, except in Saxony. They are valued for the beautiful blue they impart to glass, and are manufactured on the spot into zaffre and smalt. The first consists of the calx of cobalt simply mixed with pulverized flints, moistened and pressed into casks. The latter is the same calx fused into glass with vitrifiable earth and alkali, and reduced to a fine powder by quenching in water and levigation, or rolling in a mill. Q

Cobalt is easily soluble in the nitrous acid or in aqua regia, to which it imparts a red colour. The vitriolic acid scarcely acts on it, unless boiling and highly concentrated. The marine acid has no action on the regulus, but dissolves the calces. R

Zink is a white semi-metal, not subject to rust in the air, harder than either lead or tin, malleable in a certain degree and laminable, and so tough that a thin piece may be bent several times backward and S

 forward

forward before it breaks. Its fracture exhibits shining facets. Some time before ignition it melts; when ignited it becomes covered with a white calx, and on the heat being raised and the surface of the metal uncovered, it burns with a very bright flame, at the same time that part of the calces are driven up in the form of a white smoke, which floats in the air.

T The ores of zink, are either calces, as the zink-spar, and calamine; or mineralized with sulphur, as in pseudo-galena or black jack, and blends of various colours. The sulphureous ores require torrefaction. Zink is obtained from its ores by distillation with charcoal, in closed vessels in a reverberatory furnace, their construction being peculiarly adapted to preserve this volatile and inflammable metal from being dissipated or calcined.

U Zink is readily dissolved in acids. White vitriol (179, V) is the only saline combination of this metal found in commerce.

V Sulphur has no action on this semi-metal: whence it is easily purified, by burning sulphur on its surface when in fusion. These two substances are united in ores by the medium of iron.

W Zink is chiefly used in making brass and other metallic mixtures of the like nature (253, K, L,). It is likewise used as a solder, known by the name of spelter.

X Regulus of antimony is of a silvery white, not subject to rust, very brittle, and of a scaly or plated texture. It melts soon after ignition, and by a continuance

continuance of the heat becomes calcined, and rises in the form of white fumes. By a more moderate heat it is converted into a grey calx, fusible into a kind of glass.

The most common ore of this semi-metal is the Y
substance called antimony. It contains sulphur in combination with the regulus, is of a dark bluish metallic colour, and its fracture resembles long shining needles. The regulus may be obtained by torrefaction, by which the sulphur is driven off, and subsequent fusion with inflammable matters. In the small way, four parts of antimony with three parts of tartar and one and a half of nitre are thrown a little at a time into a red hot crucible, and the heat raised at the end so as to fuse the mass. The detonation consumes much of the sulphur, and the coaly matter of the tartar revives a considerable part of the regulus which is found at the bottom of the crucible. Or antimony may be thrown on half its weight of small pieces of iron or nails, first made white hot in a crucible, and the heat being suddenly raised, after having covered the crucible, the mass melts, regulus of antimony being at the bottom, and the iron combined with the sulphur at the top.

The mineral acids dissolve regulus of antimony Z
difficultly. The marine acid has very little effect on it; but it is soluble in a considerable degree in an aqua regia, consisting of seven parts nitrous and one marine acid, or in a mixture of the vitriolic [illegible] and

and marine, or even of the vitriolic and nitrous acids.

A Much labour has been bestowed on this semi-metal by the alchemists. It furnishes some very powerful remedies, but its medical preparations require the greatest care and attention; because variations apparently of small importance in the processes are sufficient to render its effects uncertain, and even highly dangerous.

B Regulus of antimony is used in various metallic mixtures, for printing types, speculums, &c.

C The regulus of manganese is a semi-metal of a dusky white colour when newly broken, which grows brown by spontaneous calcination on exposure to the air. It appears to be less fusible than iron, the larger pieces being scarcely ever globular. It is very hard and brittle, and becomes spontaneously calcined in the air, so as to fall sometimes into a brownish black powder, heavier than the regulus; a circumstance which does not happen when it is inclosed in a dry, well corked bottle. Its powder is magnetic.

D Manganese is the calx of this semi-metal. Its colour is either white, blue, green, yellow, red, brown, or black, according to its less or greater calcination, and the nature of the substances it may be contaminated with, of which calx of iron is the chief. The brown or black calx is too much calcined to be soluble in acids, and has less attraction for vital air than any other substance except nitrous acid.

If a globule of microcosmic salt be melted on a piece of charcoal, by means of the blow pipe, and a small portion of the black calx of manganese be added, a glass will be formed of a bluish red, or if the proportion of manganese be greater, of a full red. The tinge will however totally disappear if the fusion be continued with the interior or well defined apex of the flame. The brown or exterior part of the flame restores the colour. And this may be repeatedly done. The smallest particle of nitre added to the clear glass instantly restores the red colour: but vitriolic salts contribute to discharge it, as do likewise metallic calces, though these communicate each a tinge peculiar to itself.

The explanation of these facts appears to be this: the proper tinge communicated to glass by calx of manganese, when highly calcined, is red, but manganese with a less proportion of vital air is colourless. The fusion by the interior apex may be considered as a fusion in a close vessel, because the surrounding flame defends the globule from the contact of the air on the greater part of its surface. The reduction effected by the charcoal is therefore permanent, and produces the effect of rendering the globule transparent. But when the exterior flame is used, this is not the case; for the circumambient air, touching the globule in a much larger part of its surface, combines with it more speedily and in a greater quantity, than the small surface of contact between the globule and the charcoal is capable of absorbing.

The

The colour therefore returns. The nitrous acid in nitre calcines the manganese. Vitriolic salts are decomposed and become sulphureous by contact of the charcoal, and thus attract vital air. Metallic calces, as well by the coaly matter they often contain, as by their own nature, are more disposed to perfect combustion than the calx of manganese, and therefore destroy the red colour. That these changes do not depend on the greater or less quantity of combustible matter that may be supposed to be imparted by the interior or exterior apices of the flame, is clear, from the changes not taking place when the globule rests on a support of pure gold or silver.

6. The same phenomena with small variation take place in other glasses. Hence a principal use of manganese is made by the glass makers, in clearing their glass from the green tinge imparted to it by calx of iron, from which they cannot with sufficient facility free the materials they use. The green colour arises from iron not sufficiently calcined; manganese being therefore added in a certain dose, affords enough of vital air to render the glass colourless. But if the dose be not duly proportioned, either its own red colour or the green will prevail; the latter of which is thought to be the best.

7. A remarkable effect of combustion from the vital air in the calx of manganese, is seen in the ore called black wad, from Derbyshire. It is a brown pulverulent mass, and used as a pigment. If half a pound of this be dried before a fire,

fire, and afterwards suffered to cool for about an hour, and then two ounces of linseed oil be gradually poured on it and loosely mixed, in somewhat more than half an hour the mixture will grow gradually hot, and at last burst into a flame. This effect seems to be analogous to the inflammation of oils by nitrous acid (188, D).

The vitriolic acid attacks the regulus of manga- I
nese, and extricates inflammable air. A spongy substance, of the same figure as the regulus, however remains, which is probably an impurity. Alkalis precipitate a white calx soluble in acids.

The black calx when well calcined is sparingly K
taken up by the vitriolic acid, and this portion seems to be that which had not been well calcined; for the remainder altogether rejects the acid. That this calx is insoluble (233, I) from an over dose of vital air, is rendered clear, by adding sugar, honey, or any combustible substance, as by that means the solution is promoted and completed. The metals, not excepting even gold itself, produce the same effect.

The nitrous acid dissolves regulus of manganese L
with effervescence, occasioned by the production of nitrous air. A small residue is left. This acid acts very sparingly on the black calx.

The marine acid dissolves the regulus and also M
the white calx. It likewise takes up the black calx, which communicates to it a red colour, and takes off as much vital air to the acid as is necessary to its

its ſolution. The aerated part flies off in yellow vapours, ſmelling like aqua regia (191, s).

N Regulus of wolfram * is a brittle ſemi-metal of a ſteel colour. Its ſpecific gravity exceeds that of every other body in nature, except platina and gold (17, w); and it has not been fuſed into any maſs of conſiderable magnitude, being more refactory than mangaueſe.

O The ores of this ſemi-metal are the tungſten, a ponderous ſubſtance of a grey colour and lamellar texture, containing the metallic calx, or acid united
P to about its own weight of calcareous earth: and wolfram, a mineral of a ſtill greater ſpecific gravity, of a browniſh black, always opake, internally ſhining, almoſt like a metal, and of a cryſtallized form. This laſt is only found in tin mines, and contains about two thirds calx of wolfram, together with the black calx of mangaueſe and calx of iron.

Q If pounded wolfram or tungſten be digeſted in the marine acid, the manganeſe and iron of the former, or the calcareous earth of the latter, will be taken up in part, or extracted from the external parts of the molecules. The reſiduum, after edulcoration with water, being digeſted with volatile alkali, the wolfram calx, or acid, will be taken up in part, or extracted from the ſurface. The reſidue, after edulcoration, will be again acted upon by the ma-

* The diſcoveries of Scheele, Bergman, and the De Luyarts, are to be found in "A Chemical Analyſis of Wolfram." Printed in London in the year 1785.

rine

rine acid, which seizes another stratum of particles that were in the former digestion defended from its action by the wolfram calx, which the digestion in volatile alkali has removed. Volatile alkali being again applied, and the alternation continued for many vicissitudes, the mineral becomes almost entirely dissolved; the portions of acid contain either the calces of manganese and iron, or calcareous earth, according to the mineral made use of; and the volatile alkali contains the acid of wolfram. The addition of nitrous acid to this last precipitates a salt, consisting of the calx of wolfram, volatile alkali, and nitrous acid. This salt is soluble in R water, though sparingly, and has acid properties. The first discoverers, Scheele and Bergman, called it acid of tungsten.

Fusion of the ore with vegetable alkali, with S solution in distilled water, will afford a solution of the calx of wolfram in the alkali. This being evaporated to dryness, may be deprived of the alkali by boiling with nitrous acid, and decantation, for two or more times. The adhering acid may be driven off by calcination, and leaves the pure calx of a brimstone yellow. The same calx is also obtained by calcining the precipitate (280, R) from volatile alkali, the nitrous acid and the alkali being driven off.

The pure calx is not soluble in water, but T makes, by trituration, an emulsion of sufficient subtlety to pass the filtre, and which does not entirely subside in three months. It has not this effect

effect with the vitriolic, nitrous, and marine acids. It is completely soluble in caustic vegetable al-
u kali, by the moist as well as the dry way. A solution in water, and also in volatile alkali, of the precipitate by nitrous acid, from the volatile alkali being added to lime-water, regenerates tungsten, the acid and alkali being found in the superfluent liquor.

v From the strong disposition of the calx of wolfram to unite with alkalis and with calcareous earth, and its insolubility in acids, it may properly be considered as a metallic acid, though it may not possess enough of vital air to exhibit all the usual properties.

v By treatment in a crucible with charcoal, with a strong heat, the calx of wolfram is revived into a regulus, being a brown mass, consisting of a congeries of metallic globules, with a loss of two fifths of its weight. Calcination turns it yellow as before, and its weight becomes augmented about one fourth.

w This regulus is insoluble in the vitriolic and marine acids. The nitrous acid, and aqua regia, dephlogisticate it, and convert it into the yellow calx (280, s). It mixes with other metals, and forms peculiar alloys. Its calces tinge glass.

x Molybdena is a mineral substance, resembling plumbago, but its laminæ are larger, brighter, and in some degree flexible, so as to be very difficultly reduced to powder. In an open fire it is almost entirely volatile. It is composed of sul-

phur combined with a metallic acid. No acids act on it but the arsenical and nitrous. The first combines with its sulphur, and forms orpiment: the latter, five times distilled from it, communicates vital air, and forms the molybdenous and vitriolic acids. This last acid may be washed off with water, which at the same time carries off a portion of the acid of molybdena.

This acid is in a white dry form, very sparingly soluble in water. It has all the general properties of acids, and others peculiar to itself. It is precipitable from its solution in water by Prussian alkali, and by galls. Distilled with three times its weight of sulphur, it again produces molybdena. Y

It has been reduced into a metallic form. Z

CHAP. XX.

CONCERNING PYROPHORI; THE PHOSPHORUS OF BOLOGNA, OF BALDWIN, AND OF CANTON; OILS, ARDENT SPIRIT, AND ETHER.

THERE are many compositions that take fire on exposure to respirable air. They are called pyrophori. One of the best is thus made. Two parts of burned alum, or alum kept in a red heat till it has ceased to expand and swell; one part of charcoal, and one part of vegetable fixed alkali being mixed in powder, are to be lightly pressed C

into the bowl of a tobacco-pipe, or a ſmall crucible, ſo as to fill it about half or three fourths; the remaining ſpace is to be filled with fine writing ſand, for the purpoſe of preventing the immediate acceſs of air. This veſſel being placed in a good fire, the ſand is agitated for a few minutes by the eſcape of elaſtic fluid, and ſoon afterwards a blue flame is ſeen to iſſue from the maſs, which continues about a quarter of an hour. The red heat being continued for twenty minutes or longer, after this appearance has ceaſed, the veſſel may be taken out of the fire, and when it is perfectly cool, the pyrophorus may be knocked out, and muſt be immediately put into a well cloſed phial. A piece of this expoſed to the air for a ſhort time, becomes ignited, with ſome ſlight appearances of deflagration. and an
D hepatic ſmell. The particular or immediate cauſe of the accenſion of pyrophori has not been well explained. It ſeems as if the combuſtible ſubſtance made uſe of, enters into the compoſition of an hepar, in which the connection of the inflammable matter is ſo ſlight, that it can unite with pure air with ſufficient rapidity to produce ignition and combuſtion (125, N).

E It is a very general property of bodies, after expoſure for a ſhort time to light, to emit it again for ſome time after it ceaſes to fall upon them, as is eaſily proved by receiving them in a darkened room. Metals and water have not this property *, neither do ores, vitriols, or oil, poſſeſs it in any

* Prieſtly's Optics, p. 369.

conſiderable

considerable degree. Other bodies possess it in various degrees. Heat causes the light to be emitted more quickly, and consequently with greater intensity while it lasts, but the luminous appearance does not take place at all by mere heat without previous exposure to light. It is said, that coloured light is emitted again of the same colour. Among substances that possess this property in a remarkable degree, the chief are vitriolated ponderous earth, or ponderous spar, previously ignited among charcoal; called the Bolognian phosphorus: nitrated calcareous earth, after ignition; called Baldwin's phosphorus; and calcareous earth ignited with sulphur. This last is called Canton's phosphorus, and is thus made. Calcine oyster-shells, by keeping them in a good fire for half an hour or more, and let the whitest part be pulverized and sifted. With three parts of this powder mix one part of flowers of sulphur. Let the mixture be rammed into a crucible of about one inch and a half in depth, till it be almost full, and let it be placed in the middle of the fire, where it must be kept red hot for one hour at least, and then set by to cool. When it is cold, turn it out, and cutting it into pieces, scrape off or select upon trial the brightest parts, which, if good, will be a white powder, and may be preserved in a dry phial with a ground stopper. Exposure for a few seconds to the light of the day, will cause it to shine in the dark; or it may be rendered luminous by an electric explosion made near it.

H Oils are liquids, in general lefs fluid than water, and remarkably lefs fonorous when poured out. When heated fo as to fume, they are eafily fet on fire, and burn with a luminous flame. If the combuftion be not managed fo that refpirable air may have fufficient accefs to all parts of the flame, much fmoke is produced. They leave a coal behind.

I In the combuftion of oil, for the œconomical purpofe of giving light, a wick is made ufe of, confifting of vegetable fibres, ufually cotton. Thefe being dipped in the oil, one end of the wick is made to protrude, and is fet on fire. The capillary attraction (1, 46, w) fupplies more oil, accordingly as that in the heated part of the wick is carried off by the rarefaction and combuftion. If the wick be too large, the internal part of the flame will want air; if it be too long, more oil will iffue out of its pores in vapor than can be completely burned. In either cafe fmoke will be produced. But by a due attention to the figure and magnitude of the wick and the fupply of air, a bright flame may be produced without fmoke. This is done in the excellent lamp of ARGAND.

K Oils are diftinguifhed into the unguinous and effential. The former are infipid, and without fmell, not foluble in ardent fpirit, nor volatile in the heat of boiling water. Acid of fugar has been obtained from them. The latter have a ftrong fmell and tafte; are foluble in ardent fpirit, and volatile in the heat of boiling water. Animal fats

fats resemble unguinous oils, excepting the oil obtained by distillation from the gelatinous substance of animals. This may be brought to resemble ether by repeated distillations. Resins are of the nature of essential oils.

Spirit of wine, or ardent spirit, is obtained by distillation from substances that have undergone the vinous fermentation (212, F, H), and are not arrived at the acetous. When well concentrated, it is very volatile and fluid, has never yet been congealed, mixes with water in all proportions, and with an affinity sufficiently powerful to take it from most saline substances; highly inflammable, so as to burn without a wick, even when cold, and produces neither soot nor coal. Its flame is bluish, and not very luminous. L

Ardent spirit unites with acids, and renders them milder than can be supposed to arise from mere dilution. N

If vitriolic acid be added to spirit of wine, and the mixture submitted to distillation, the products are first a very pure spirit of wine, next a liquor called vitriolic ether, and, lastly, an oil. In this process it appears, that the action or combination of the acid is capable of converting the spirit into oil, and that ether is an intermediate substance between spirit and oil. O

Ether is soluble in ten times its weight of water. It is extremely light (18, W), and so volatile, as to convert water into ice in a warm room, if the water be included in a small bottle, or tube, P

conſtantly wetted on the outſide with this fluid (123, K). It is highly inflammable, burning with a white luminous flame, and ſome appearance of ſoot, but leaves no coal.

Q Ethers may be made with other acids as well as the vitriolic.

BOOK III.

SECTION II.

Of Magnetifm.

CHAP. I.

CONCERNING MAGNETISM; THE METHODS OF COMMUNICATING IT, AND THE VARIATION OF THE COMPASS.

THAT remarkable property which iron poffeffes, A of becoming magnetical, feems to ftand alone among natural phenomena. It is the only inftance of permanent attraction which is fufficiently ftrong to become the object of vulgar attention; and philofophers obferve its effects with furprize and admiration; while the moft cautious and rational are obliged to confefs that the caufe is entirely unknown.

A ftrait bar of iron, which in the northern B parts of the world has ftood a long time in a vertical pofition, is found to have acquired the property of attracting other iron at its extremities; and, if fupported in a veffel, fo as to float at liberty upon water, conforms itfelf to a direction nearly in the plane of the meridian; the end,

which during its perpendicular ſituation was downwards, always pointing towards the North. This bar is ſaid to be magnetical; and the unknown cauſe of theſe and other concomitant effects is called magnetiſm.

c Magnetiſm may be given to iron, or rather ſteel, by many methods. The diſpoſition to conform to the plane of the meridian is called polarity, and is of ſuch importance in its application, that the modern art of navigation could not be practiſed without it. The mariner's compaſs is thus conſtructed. A flat thin bar of ſteel, rendered magnetical, is faſtened underneath a circular card, divided into points (56, K), ſo that the direction of its length may correſpond with the line N S fig. 132). This bar is perforated in the middle; and in the perforation is fixed a braſs cap, hollowed out conically, which conſequently is in the center of the card. The card thus provided with a magnetical bar, is then ſupported horizontally, by placing the cavity of the cap on an upright metallic point, and is therefore at liberty to revolve into any horizontal poſition. But the bar, which is uſually termed the needle, conforming itſelf to the meridian, cauſes the fleur de lis of the card to point to the North: conſequently, the other diviſions muſt denote the reſpective bearings of the points of the compaſs. This card being thus ſuſpended in a hollow box, and defended from the wind by a pane of glaſs, with the addition of a contrivance to prevent the effects of the agitation

tion of the ſhip, is the mariner's compaſs; by the help of which, veſſels are enabled to ſteer their courſe with ſafety in the darkeſt night, and at any diſtance from ſhore.

In the examination of the magnetiſm of various bodies, as, for example, platina (240, B) or nickel, it may be of importance to know the degrees of magnetiſm as diſcoverable by experiment, which are the following. The weakeſt is when a body floating on water ſlowly follows a ſtrong magnet, held almoſt touching it; the next is when the magnet can repel as well as attract the body; a ſtill ſtronger degree is, when the body conforms its poſition to that of the magnet held over it; the fifth is, when the body left to itſelf aſſumes a particular poſition, and returns to it when diſturbed; the ſixth is, when the body, taken out of the water, and brought near a light compaſs needle, cauſes it to deviate from the magnetic meridian. All ſtronger degrees of magnetiſm may be obſerved by leſs delicate methods. D

The ends of a ſimple magnetical bar are called its poles; and that pole, which, when at liberty, would point to the North is called the North-pole, and the other is called the South-pole. E

Univerſally, in two magnetical bodies or magnets, an attractive force obtains between the North-pole of one, and the South-pole of the other, and a repulſive force obtains between poles of the ſame name. But the repulſive force which exiſts between F

tween poles of like names, but unequal power, is changed into attraction, when the diſtance is ſufficiently ſmall. From theſe criterions it is eaſy to determine the names of the poles of a magnetical bar, by applying it near the ſuſpended magnet, whoſe poles are known.

G If a bar of iron, which is not magnetical, be held in a vertical poſition, in North latitude; its lower point becomes a North, and its upper a South pole; and theſe poles may be reverſed inſtantly, and as often as required, by reverſing the poſition of the ends; for the lower will always be North, and the upper South. But a few ſtrokes with a hammer at the upper end, will fix the poles in their laſt poſition, ſo that, after the reverſing it, the hammered end will ſtill continue to be ſouth, though loweſt. Yet, the magnetical power is much the greateſt when the hammered end is uppermoſt, and the effect of the hammering diſappears in a few hours.

H A bar of iron being ſuſpended on an axis, in a very nice equilibrium, the North end preponderates when the bar is rendered magnetical, ſo that it becomes inclined to the horizon, in an angle of about ſeventy degrees in theſe latitudes. This is called the dip, and decreaſes in places more to the ſouthward, and even becomes inverted in places ſituated conſiderably on the other ſide of the equator. The bar thus ſuſpended is termed the dipping-needle.

Magnetiſm may be given to a bar of iron, by placing it firm in the poſition of the dipping-needle, and rubbing it hard all one way with a poliſhed ſteel inſtrument. Iron alſo becomes magnetical by ignition, and quenching it in water, in the poſition of the dipping-needle. I

The touch of a magnet communicates the like virtue to other iron, but the quantity or degree which the ſame magnet can communicate, depends greatly upon the manner in which the touch is performed. If two equal, ſtrait and uniform magnetical bars, with flat ends, be placed together endwiſe, the contrary poles touching each other, they will form one ſingle magnet, and will communicate a ſtrong degree of magnetiſm to another bar by the following proceſs: let the laſt mentioned bar be laid in the direction of the magnetical meridian, and let the others, each of which ought to be at leaſt as long as the bar to be impregnated, be laid upon it in their conjoined ſtate, ſo that the place of junction may be over the middle of its length, and their poles in the proper direction. Then ſeparate the two magnets, by drawing them aſunder along the ſurface of the bar, and continue to ſeparate them till their ends are at a conſiderable diſtance from its ends. Join them again, without altering the ſituation of their poles, by a circular motion of the hand, ſo that they may meet at ſome diſtance above the center of the bar, and lay them again upon it as before. K

Repeat

Repeat this operation on both ſides of the bar till it has acquired a ſufficient degree of magnetiſm. The maximum is generally obtained after twelve or fourteen ſtrokes.

L A bar of iron receives the touch more ſtrongly when it is ſupported by, or in contact with, another much larger; and a combination of magnetical bars will produce a much greater effect than a ſingle one. Soft ſteel acquires the magnetical power more readily, but does not preſerve it ſo long as hard ſteel. On theſe, and other conſiderations, experiments have been multiplied, and various methods invented, of giving to ſteel the utmoſt degree of magnetiſm it is capable of re-
M ceiving. For example, ſix bars of ſteel may be rendered ſlightly magnetical, by affixing each ſucceſſively to a poker, and ſtroking it ſeveral times from bottom to top with the lower end of an old pair of tongs; care being taken to keep both the poker and tongs in a vertical poſition. For, theſe utenſils, by long ſtanding in a vertical poſition, are almoſt always poſſeſſed of a fixed magnetiſm; the lower ends being North poles. Now, if four of the ſix bars be united into a thick compound bar, the magnetiſm of the remaining two may be greatly increaſed by touching with it. Theſe two bars may then be ſubſtituted in the room of the two outermoſt in the compound bar, which will become more powerful by the exchange, and the two, which were taken from the compound bar, may be touched in their turn. Thus, by reiterated changes,

changes, and touching, the bars will at length acquire as much magnetiſm as they are ſuſceptible of; and more than they can retain for any long time.

The force of magnetiſm is exerted through all N ſubſtances, iron excepted, and it has not been obſerved that it ſuffers the leaſt diminution by the interpoſition of any foreign matter. Magnetiſm is deſtroyed by ignition; and a heated bar of iron is not attracted by the magnet till it is juſt upon the point of loſing its redneſs.

The loadſtone is a ponderous ore of iron, O uſually of a dirty black colour, and hard enough to emit ſparks with ſteel. It is found in moſt parts of the world, and poſſeſſes a natural magnetiſm, acquired moſt probably from its ſituation or poſition with reſpect to the earth. This magnetiſm may be, as it were, concentrated, and made to act much more ſtrongly by covering its polar extremities with ſteel. The ſteel thus applied is termed the armour of the loadſtone, and requires ſome management, as to figure and thickneſs, to produce the greateſt poſſible effect. Formerly all magnetiſm was originally obtained by communication from the loadſtone, but the power of impregnated ſteel-bars ſo much exceeds that of the natural ſtone, that this latter is little eſteemed, except as an object of curioſity. The magnetiſm of the loadſtone is in all reſpects ſimilar to that of a bar of iron or ſteel.

The attraction or repulſion of two magnets de- P creaſes as the diſtance increaſes, but not according

to any ratio of the diſtance. On this account a magnetical bar, which is at liberty to aſſume any horizontal poſition, as, for example, a needle floated on water by means of cork, or the needle of a mariner's compaſs, being brought into the vicinity of another magnet, will aſſume ſuch a ſituation as ſhall conform to the attractive and repulſive powers as much as poſſible. Thus, if a ſuſpended magnetical needle be brought near another magnet, it will place itſelf in a poſition parallel to the axis of the magnet, if the poles of contrary names in each be mutually equidiſtant; but if the North pole of the ſuſpended needle be nearer the South pole of the magnet than the two other poles are to each other, its North end will be moſt attracted, and conſequently muſt incline, ſo that the axis of the two magnets will form an angle greater or leſs, according to circumſtances. Suppoſe now a ſmall magnetical bar, ſuſpended ſo as to be capable of aſſuming any poſition whatſoever, be placed upon, or near the ſurface of a very large globular magnet. It is evident, in this caſe, that the two ends of the ſmall bar, being reſpectively attracted by the contrary poles of the globe, will always be found in a plane paſſing through thoſe poles: or in other words, if circles or meridians be ſuppoſed to be deſcribed on the globe, interſecting each other in thoſe poles, the magnetical bar muſt always be in the plane of one of them. But its ſituation, with regard to the ſpherical ſurface, will be governed by the exceſs of

attraction in the nearest pole. If the bar be suspended immediately over the North pole of the magnet, it must stand perpendicularly, with its South end downwards; but if it be gradually removed along the surface, towards the South pole, the increasing action of this last pole will cause it gradually to incline that way. At the equator it will rest parallel to the surface; and in approaching still nearer the last mentioned pole, its North end will incline towards the surface, till at length it will stand perpendicularly over the South pole of the great magnet, with its North end downwards. For the sake of conciseness, the poles of the great magnet are supposed to be equally strong; which, however, is seldom the case.

This reasoning may be exemplified by placing a small piece of sewing-needle on the surface of a spherical magnet or loadstone. Its position is found to vary according to its situation with respect to the poles. For the same reasons, steel-filings, gently dusted through a rag upon a magnet, adhere to it in a very curious and amusing manner. The filings, acquiring magnetism by the contact, adhere together, and form a number of small magnets, which arrange themselves in conformity to the attractions of the poles of the original magnet.

From observations of this nature, it was very early supposed, that the globe of the Earth acts as a large magnet, upon all other magnets: whence they naturally tend to conform to the meridian or

t line which joins the poles of the Earth. And the dipping of the needle is readily shewn to arise from the vicinity, and consequent stronger attraction of the pole towards which the inclination is made.

u The needle of the mariner's compass varies from the true direction of North and South. The angle formed between the magnetical axis of the needle and the meridian of a given place is called the variation of the compass, and differs in different places both in quantity and direction of the needle. From the phenomena of the variation it is proved, that the magnetic poles of the Earth must be more in number than two, and that they do not coincide with the poles about which the diurnal rotation is performed.

v The variation of the compass does not continue fixed and unalterable at a given place. Thus, at the Cape of Good Hope in Africa, near which, at its first discovery by the Portuguese, there was no variation; the North point of the compass, in 1622, varied about 2°. to the westward: in 1675, it varied 8°. W. in 1700, about 11°. W. in 1756, about 18°. W. and in 1774, about $21\frac{1}{2}$°. W. Regular, though very different mutations have been observed in almost every other place on the globe. The needle of the compass is likewise subject to a small diurnal change of position, and is sometimes considerably agitated during the appearance of the aurora borealis.

w The observations which relate to the magnetism of the Earth have not been continued long enough

to

to afford a foundation for a good theory. Dr. Halley's hypothesis, though formed near a century ago, still possesses as great a share of probability as most that have been offered since. He supposes the Earth to consist of two distinct parts, an external shell, or hollow sphere, and an internal nucleus or globe, loose and detached in the cavity, having the same center of gravity with the external part. Each of these parts he regards as a separate magnet, endued with two poles, their magnetical axes not being coincident. A compass-needle on the external surface must therefore be acted upon, as if by a magnet with four poles. From the phenomena he determines the situation of the several poles, and thus explains the variation. But as the variation changes in process of time at any given place, it follows, that these poles do not keep the same position with respect to the surface of the Earth, and to each other. This movement he accounts for, by supposing that the diurnal motion of the Earth was impressed from without, and that the velocity of the internal part, or nucleus, is somewhat less than that of the external part, or shell. Consequently the nucleus must seem to revolve slowly to the westward, and its poles must describe lesser circles about the poles of the Earth. And as the relative position of the four magnetical poles to each other, and to the poles of the Earth, is changed, so must likewise the direction of the

needle, or the angle it makes with the meridian, be altered.

Y Thus, a kind of regularity prevails in the increase and decrease of the variation, and also the direction of the variation which ships observe as they sail to various parts of the ocean. In the Atlantic ocean to the North, and eastward, and all over the Indian ocean, except in the bay of Bengal, a westerly variation obtains; but to the westward of a certain line, at which there is no variation, all along the coast of South America, and in the Pacific ocean, as far as the 140th degree of west longitude, an easterly variation is observed; and in the whole Pacific ocean besides, the variation is probably to the west, unless it may be conjectured that an easterly variation may be found in the regions to the northward.

Z When the variation changes quickly in running upon a parallel, as is the case in the southern Atlantic, and great part of the Indian ocean, the longitude may be determined with a considerable degree of correctness at sea. For the magnetic azimuth of the Sun may be easily observed in moderate weather to the certainty of a less error than ten minutes of a degree; which in the southern Atlantic ocean answers to about twice that quantity in longitude. By comparing the observed variation with a chart, the longitude may be known. The principal impediment in the way of this method is, the want of such a chart occasionally renewed.

The

The best modern opinion concerning the cause of the change of variation of the compass is this. From the magnetism of the Earth as well as from the products ejected by volcanos (227, F), it is established that vast quantities of iron exist in the bowels of the Earth in various states. The same volcanic eruptions, and the phenomena accompanying them, likewise shew that chemical processes, on a scale of prodigious magnitude, are continually carried on in those regions. The ferruginous combinations being varied by these, it must happen that immense masses will be either more or less phlogisticated, according to the nature of the process by which such change is made. Now it is well known that iron and its combinations are more susceptible of magnetism the nearer the metal approaches to the reguline state; and consequently the properties of the whole terrestrial magnet must change accordingly. A

BOOK III.

SECT. IV.

Concerning Electricity.

CHAP. I.

OF THE ELECTRIC MATTER; AND THE METHODS AND APPARATUS FOR MAKING EXPERIMENTS WITH IT.

A If a tube of glaſs, an inch and half in diameter and about three feet long, be rubbed, by repeatedly drawing the hand or a piece of leather from one end to the other, it will become electric. So that ſmall flaſhes of divergent flame, ramified ſomewhat like trees bare of leaves, will dart into the air, from many parts of the ſurface of the tube, to the diſtance of ſix or eight inches, attended with a crackling noiſe; and ſometimes ſparks of more than a foot in length will fly along the tube to the rubber. This luminous matter is called electricity, or the electric matter, and will fly from the tube to other bodies brought within a certain diſtance.

If

If a homogeneous body be presented to the excited tube, so as to receive electricity from it, and the electricity remain at or near the end or part presented, without being communicated to the rest of the body, it is called a non-conductor or electric. But if, on the contrary, the electricity be thus communicated to every part, the body is called a conductor, or non-electric. In the usual temperature of the atmosphere, metallic substances, charcoal, and water, are conductors; most other bodies are non-conductors. B C D

A conductor cannot be electrified while it communicates with the earth, either by direct contact or by the interposition of other conductors, because the electricity is immediately conveyed away to the earth. But if a conductor be supported by an electric, so as not to communicate with the earth, it is said to be insulated. E F

The greatest quantity of electricity is collected on the surface of a non-conductor, when it is rubbed by a conducting substance. If the rubber be insulated, it will also be put into an electric state, so that sparks will pass between it, and other neighbouring bodies. G

If an insulated conductor be electrified, either by friction, communication, (302, B) or otherwise, it will be deprived of its electric state by the drawing of a single spark from any part thereof by another uninsulated conductor, because of the facility with which the electric matter is conveyed through its substance. But non-conductors, similarly treated, H

are deprived of their electric ſtate only in the vicinity of the place from which the ſpark was drawn.

I A mutual attraction is exerted between a body in a ſtate of electricity, and other non-electrified bodies, which laſt, if not large and heavy, will fly through the air to the electrified body, where they remain till they have, by communication, acquired the ſame ſtate, when they are repelled. If an uninſulated conductor be at hand, it will attract the ſmall body thus electrified, and deprive it of its electric ſtate. So that it will be again attracted by the electrified body, and repelled as before, and will continue to paſs and repaſs between the two for many viciſſitudes, till the electric ſtate is entirely deſtroyed.

K No experiments have yet been made, that ſhew wherein the difference between electrics and non-electrics conſiſts; but whatever the conducting power may depend on, it ſeems to be governed by the heat of the body: glaſs, reſin, baked wood, air, and many other non conductors, are conductors when made very hot; and, on the contrary, ice cooled to 13° below 0, on Fahrenheit's ſcale, becomes a non-conductor or electric body.

L There is therefore ſome ground to conjecture that the diſpoſition to conduct electricity is produced in metals by a very low degree of heat, in water by a greater, and in reſins and glaſs by degrees ſtill greater; or generally that there is a certain degree of heat at which a given body may be

at

at the medium between perfect conducting, and non-conducting, above which degree it becomes a conductor, and beneath, a non-conductor. If this M be true, it will follow, that conductors are bodies whose electric or non-conducting state is placed at a temperature far below that which is usual in the atmosphere, and that non-conductors are those whose conducting state is placed at a degree of heat far above the mean temperature.

That electricity is real matter, and not a mere N property, seems to be evident from a variety of circumstances. When it passes between bodies, it divides the air, and puts it into those undulations (65, N) in which sound consists. It emits the rays of light in every direction, and those rays are variously refrangible, and colorific, as other light is. And if light be acknowledged to be matter, it is contrary to reason and experience to suppose, that the thing which emits it should not likewise be material. Neither are the other senses unaffected at its presence; its smell is strongly phosphoreal or sulphureous, so that when the air of a room is rendered highly electric, many persons have complained of an unusual and disagreeable sensation in the head from that cause. The sense of feeling is a witness of its presence, not only from the sparks, which, when received from the conductor of a powerful machine, are very pungent, and will pass through two or three persons standing on the ground, but also from the shock, whose effects are to be described: and a stream of the electric

matter received on the tongue has an evidently ſubacid taſte, which remains ſome little time after.

O As the exciting a tube is very laborious for the operator, and the electricity procured by that means is ſmall in quantity, globes or cylinders are much more uſed. Theſe, by a proper apparatus, are made to revolve on their axes after the manner of a grindſtone, and a rubber of leather is applied to the equatorial parts of the revolving glaſs, which become electrical by the friction. The electricity of the globe is received by a metallic conductor, inſulated by a glaſs-foot, or ſupporter. This conductor being conſtantly electrified, and at the ſame time ſteady and motionleſs, is much better adapted for making experiments than the globe itſelf.

P A cylinder or globe thus fitted up to revolve on its axis, and provided with a rubber and an inſulated conductor, is called an electrical machine. The contrivances for the revolution of the cylinder or globe vary in different machines, as likewiſe the method of inſulating the conductor. The conductor is in general ſupported by a ſtick of varniſhed glaſs or baked wood, and ſometimes it is ſuſpended by ſilk ſtrings.

Q Fig. 162, repreſents an electrical machine. The glaſs cylinder c, is one foot in diameter and nineteen inches long, and is turned by a wheel and ſtring, as ſhewn in the drawing. The rubber or cuſhion is ſupported behind the cylinder by two upright ſprings that appear beneath, and are faſtened

faſtened to two croſs bars of glaſs. B is the conductor ſupported on two pillars of glaſs. From the end neareſt the cylinder, iſſue ſeveral points; and at the other end the ball F projects by means of a wire. The ball E is not inſulated, and ſerves to draw the ſpark from F. D is a chain, uſually hung to the cuſhion. The ſparks given by the conductor of a machine of this conſtruction and magnitude are from 12 to 14 inches long.

Fig. 163, is a drawing of Nairne's patent electrical machine. The cylinder C is ſeven inches in diameter and about one foot in length, but the length of the rubber is no more than eight inches. The working parts at the end of the cylinder are entirely of wood, and are ſupported by two pillars of varniſhed glaſs each of a foot in length. The conductors A and B, are ſupported by like pillars of the ſame dimenſions. The two conductors are made of tin, and lie parallel to the length of the cylinder. They are exactly alike, excepting that the rubber is fixed between the conductor A and the cylinder, and a row of metallic points iſſue towards the cylinder from the other conductor B. The inſulation of this excellent ſmall machine, is ſo perfect, that on the addition of a larger conductor to either of the others, it will give denſe ſparks of nine inches long to a ball of $2\frac{1}{2}$ inches diameter.

CHAP.

CHAP. II.

CONCERNING EXCITATION; THE TWO DIFFERENT STATES OF ELECTRICITY, AND THE EFFECTS OF POINTED CONDUCTORS.

S VERY little electricity is excited by the friction between two electrics or two conductors. The most favourable circumstances for producing this effect, seem to be, when a perfect electric is rubbed by a perfect conductor (302, G).

T The rubber of an electrical machine is usually made of soft leather stuffed with hair, and the rubbing part is smeared with an amalgam of zink and quicksilver with a little tallow, the whole being so proportioned as to have the consistence of paste. The glass cylinder in its rotation, passing in contact with this metallic soft substance, becomes electrified, and its electricity is prevented from flying back in sparks to the rubber or being dissipated into the air, by a piece of silk sewed to the rubber, and passing over its surface and thence half way round the cylinder, to which it adheres by the electric attraction.

U The electricity thus excited, is much stronger in dry frosty weather than when the atmosphere is damp, and consequently a better conductor of electricity. The management of the operator will also

make a prodigious difference. No theory of what happens in the excitation of electrics, has been offered that deſerves to be mentioned; and it is owing to our imperfect knowledge of this ſubject, that the moſt ſkilful operators ſucceed by an attention to circumſtances relating to the conſiſtence of the amalgam, the roughneſs or ſmoothneſs of its ſurface, its freſhneſs, the poſition and management of the ſilk, and other matters that can hardly be deſcribed, ſo as to aſſiſt the young electrician. The following directions however ſucceed very well.

Every part of the apparatus muſt be carefully wiped with a dry warm cloth, or old ſilk handkerchief, in order that the electricity, when collected, may not be conducted off by adhering moiſture or damp (302, D). The amalgam ought to abound with quickſilver, and to have no more tallow than is ſufficient, when applied to the cylinder, juſt to diminiſh its brightneſs without ſmearing. It muſt be rubbed on the rough ſide of a piece of leather, paſted on a card, in very ſmall quantity. The cuſhion and ſilk muſt be carefully bruſhed or wiped before it is put in its place. This done, turn back the ſilk ſo that its looſe part may not touch the cylinder, and begin to turn the machine, at the ſame time applying the amalgamed leather to the cylinder. After a few turns the electricity will be heard in a kind of ruſtling noiſe near the hand and cuſhion. Remove then the amalgamed leather, and replace the ſilk on the cylinder, to which it will immediately adhere.

adhere. The friction will now be much greater than before, as will be perceived by the difficulty of turning the handle, and the electricity will be seen along the edge of the silk in long diverging ramifications that dart into the air with noise. These fly to the points of the prime conductor when applied, and, by means of this last, the sparks may be drawn, or other experiments performed.

w It is not well settled whether a velocity of rotation in the cylinder, greater than the hand can produce with a single winch, be of any advantage in electricity. From a few trials, not sufficiently diversified, the fact seems to be, that there is a certain velocity of turning by which more electricity is obtained, in a given number of turns, than by any velocity considerably greater or less; and that this necessary velocity is least when the excitation is most powerful. A cylinder of seven inches diameter, well excited, will afford its maximum of electricity in a turn by a moderate rotation with a single winch, and the adhesion of the silk will render the turning sufficiently laborious. But whether the labour of the operator would be better employed in producing more turns in a given time by means of a wheel, though the excitation were less powerful, remains to be decided.

x If the amalgam be applied on the cushion itself, instead of a separate leather, the excitation will be more uniformly the same, though rather less strong. When the separate leather is used, it is necessary

to apply it to the cylinder from time to time, to keep up the excitation. One of the chief advantages of this laſt method appears to be, that a ſtrong excitation may at any time be produced by taking off the cuſhion and wiping it and the ſilk very clean, at the ſame time that the old amalgam is ſcraped off the leather, and replaced by the ſize of a pea of freſh amalgam; whereas in the other method, it not unfrequently happens, that the operator is obliged to have recourſe to a variety of manœuvres without ſucceſs.

If of two conductors, ſeparately inſulated, one be connected with the inſulated rubber, and the other placed near the cylinder, ſo as to be electrified by it, they will both exhibit ſigns of electricity; but that conductor, which is electrified by the cylinder, will attract thoſe bodies which are repelled by the other conductor that received its electricity from the rubber.. And theſe conductors, if brought near each other, will emit ſparks, and act on each other in every reſpect ſtronger than on other bodies. If they be brought into contact, the electricity of the one will deſtroy that of the other; and notwithſtanding the electric matter appears to flow or paſs from the cylinder to its conductor, the two thus conjoined will exhibit few or no ſigns of electricity.

The ſenſes cannot diſtinguiſh the direction in which the electric matter moves. The hypotheſis moſt generally admitted, is that electricity is an uniform fluid, capable of being rarefied or con-

denſed,

densed, and that in the common electrical machine it passes from the cylinder to the conductor with points. On this supposition this conductor must, when electrified, possess a greater quantity than is natural to it; and since the cylinder affords very little electricity when the rubber is insulated, it will follow that it receives its electricity from the rubber; for unless the rubber be at liberty to receive an equal quantity from the earth, that is, unless it be uninsulated, it can part with but a very small quantity to the cylinder. Still retaining the same supposition respecting the course of the electric matter, it follows that the rubber, when insulated, must lose a part of its natural quantity by friction with the cylinder, and consequently a conductor communicating with it must be negatively electrified. It is not therefore so much to be wondered at, that the actions of the two conductors should be contrary, and that when in contact they should exhibit no signs of electricity; for the cylinder at the same instant that it imparts the electric matter to one conductor, exhausts an equal quantity from the other, which is connected with the rubber. If the direction of the electric matter be supposed to be contrary to what is here assumed, the effects must still be the same.

A The principal circumstance whereon the prevailing opinion concerning this direction is founded is, that if the conductor, which derives its electricity from the cylinder, be made sharp or angular

angular at any part, not very near the cylinder, a diverging cone of electric light will be seen, whose vertex is the point itself, and the electric phænomena will be much diminished. But the conductor, which is connected with the rubber, though its effects be equally diminished by a similar circumstance, will never exhibit the cone of rays, but is only tipped at the point with a small globular body of light. The cone has been thought to resemble the rushing out or emitting of light, and the globe the appearance of the imbibing or entrance of the electric matter; whence the name of positive electricity has been adopted for that of the cylinder, and negative for that of the rubber. The terms will be used in the same sense, in this work, though it must be confessed, that the propriety of their application is still doubtful.

If electricity be produced by the excitation of a B
globe or cylinder of sulphur or resin, the states will be reversed; the rubber will be positive, and the cylinder, with its conductor, will be negative. This was formerly thought to depend on the nature of the electric body, and the two states of electricity were distinguished by the names of vitreous and resinous electricity, but it has since been found, that the difference, in most cases, arises from the relative smoothness of the surfaces of the electric body and its rubber when compared with each other.

It seems to be a rule, that the smoothness of the C
two bodies obtains the positive state. Baked wooden

wooden cylinders, with a ſmooth rubber of oiled ſilk, become negative, but with a rubber of flannel poſitive. Glaſs, made rough by grinding with emery, excited with new ſoft flannel, is negative, but with dry oiled ſilk, rubbed with whiting, poſitive; but if the glaſs be ſmeared with tallow, and wiped with a cloth, then the oiled ſilk, by rubbing, becomes poliſhed, and the tube becomes negative, as at firſt; if the oiled ſilk be again rubbed with whiting, it excites a poſitive ſtate on the greaſed tube; but then the ſilk has again acquired a poliſh, the tube becomes again negative. Even poliſhed glaſs may be rendered negative by rubbing with the hairy ſide of a cat's ſkin.

D Bodies poſſeſſed of ſimilar and equal ſtates of electricity, repel each other; bodies poſſeſſed of oppoſite ſtates of electricity, attract each other; and bodies in a mean or natural ſtate are attracted by all electrified bodies whatever. But as we have no clear conception, or adequate idea, of any mechanical proceſs by which attraction may be cauſed, all our reaſoning on the ſubject muſt be purely hypothetical (1. 25, x), for want of probable grounds to proceed on. If ever this property of matter, whoſe origin at preſent is ſo little underſtood, ſhould be deduced from ſome ſimpler cauſe, there is great reaſon to think that it will be in conſequence of electrical diſcoveries.

E If the inſulated prime conductor of a machine be well poliſhed, and without corners or angles,

it will retain its electric ſtate very well, and will emit ſtrong ſparks upon the approach of any uninſulated conductor. If the uninſulated conductor be broad, round, and poliſhed at the end, the ſparks will be ſhort and denſe, and will produce a conſiderable ſound; if leſs broad, the ſpark will be long, crooked, and leſs ſounding; if the breadth be ſtill more diminiſhed, the conductor begins to come under the denomination of a pointed body (311, A), the electric matter paſſes to it from the prime conductor, through a great ſpace of air with a hiſſing or ruſtling noiſe, and in a continual ſtream: a ſtill greater ſharpneſs enables the electricity to paſs over a greater ſpace, but ſilently, and nothing is ſeen but a ſmall light upon the point. If a ſimilar point iſſue from the prime conductor, and the uninſulated conductor be round and poliſhed, the ſame effects happen in like ſituations; but if both be pointed, the electricity is more readily diſcharged: and in all theſe caſes the appearance of the electric matter at the point of the prime conductor will be that which is peculiar to its electricity, a large divergent cone if poſitive, or a ſmall globular light or cone if negative, and the light at the point preſented to the prime conductor will be diſtinctive of the contrary electricity. Whether a pointed conductor be electrified poſitively or negatively, if the noſe be brought near the point during the electrization, a wind will be felt blowing from the point, and the

ſenſe will be affected with a ſulphureous or phoſphoreal ſmell.

F The reaction of the force by which the air is put into motion, is exerted on the pointed body. This is ſhewn by a pleaſing experiment with an electrified wire; thus to the middle of the wire, or rather between two wires that lie in the ſame line, is affixed a center-cap like thoſe uſed in ſea-compaſſes, ſo that the wire may eaſily be moved on a point in an horizontal direction, as magnetical needles are; and the ends of the wire are pointed and bent contrary ways, to point in the direction of the tangent to the circle deſcribed by them. Now if this wire thus ſuſpended on a point, be inſulated and electrified, its ſharp ends will become luminous, and it will revolve in a direction contrary to that in which its ends are bent; or if it be ſuſpended on an uninſulated point, and brought near the electrified prime conductor, the ſame effect will follow.

G It may be thought ſtrange that the air ſhould iſſue from an electrified point, whether its electricity be poſitive or negative. It is eaſy to conceive that the iſſuing out of the electric matter may cauſe the air to move in the ſame direction, but it appears ſtrange, that the electric matter ruſhing towards a point ſhould cauſe the air to move directly contrary, that is to ſay, likewiſe from the point. But if the circumſtance be examined more narrowly, the difficulty will vaniſh. For it is highly probable that the electric matter paſſes

paſſes too ſwiftly (I. 40, Z) to excite any motion in the air but that undulation wherein ſound conſiſts (65, N); to which may be added, that if the electric matter do act on the air to put it in motion, the air muſt react with an equal force; and therefore that a current of air blown againſt the courſe of the electric matter muſt affect its appearance, by retarding the rays and deflecting thoſe againſt which it ſtruck obliquely: the contrary to which is by experience, known to obtain; for the luminous cones (314, E) are not ſenſibly affected by ſuch treatment. The air being thus indifferent as to the motion of the electric matter, its motion may be ſhewn to depend on the eſtabliſhed principles of electricity. The point is electrified either poſitively or negatively, and the air, immediately oppoſite and contiguous to the point, muſt, by the emiſſion or exhauſtion of the electric matter, become ſtrongly poſſeſſed of an electric ſtate of the ſame kind with that of the point: it is therefore repelled (313, D) and replaced by other air which is alſo electrified and repelled, by which means a conſtant ſtream is produced blowing from the point, and that equally whether the electrization be poſitive or negative. And, as action and reaction are equal and contrary, the point repelling the air muſt itſelf alſo be equally repelled in the contrary direction; whence the horizontal wire above deſcribed is turned, and that always one way, namely, contrary to that in which the air is moved, or to the direction of its bent points.

CHAP. III.

OF THE COURSE OF THE ELECTRIC MATTER THROUGH THE COMMON AIR, AND THROUGH AIR VERY MUCH RAREFIED, WITH A DESCRIPTION OF AN INSTRUMENT FOR DISTINGUISHING THE TWO STATES OF ELECTRICITY.

H THE air, being a non-conductor, muſt be claſſed among electric bodies; and the prime conductor of an electrical machine being ſurrounded with air retains its electric ſtate much better than it would do without that circumſtance. For the electric matter cannot paſs to or from the conductor with the ſame facility as if this impermeable ſubſtance were not interpoſed.

I When air is ſpoken of as impermeable and electric, it muſt not be underſtood as being perfectly ſo, but as being moſtly compoſed of non-conducting parts. There is always moiſture enough in the air to reſtore the natural ſtate to electrified bodies in a few hours. It is likewiſe permeable, as all other electrics are, by the force of the electric matter which divides it or ſeparates its parts: when this happens to a ſolid electric, a hole is made through it.

K Long ſparks are always crooked in various directions, like lightning; which ſeems to be cauſed

caused by the electric matter passing through those parts of the air in which the best conductors are found. Indeed there is reason to think that electricity always requires a conductor to enable it to pass from one body to another. For if a glass syphon, whose legs are equal, and respectively more than thirty inches long, be filled with boiling mercury, and the ends inverted into basons likewise containing mercury, a double barometer (31, z) will be formed, whose upper or arched part will be absolutely void of air. Then if one of the basons be insulated and electrified, the electricity will not pass from the mercury in one leg, through the void, to that in the other; but upon admitting a small bubble of air, it is immediately seen passing through the vacant space in the form of bright flashes or flames. In the vacuum of the air-pump the electric matter will pass and appear luminous between conductors, how distant soever, forming a beautiful appearance, that very much resembles the northern lights or aurora-borealis. But it is found that in high degrees of exhaustion the light is less the less air is left in the receiver. It seems, on consideration of these circumstances, that the electric matter cannot pass through the more perfect vacuum, for want of a conductor, but that the conducting part of the air when introduced, answers the purpose, while the resistance of the electric part, being very small, on account of the rarefaction, suffers it to pass from one con-

ductor to another, through much greater ſpaces than it can paſs through in the open air.

L This opinion is ſomewhat more confirmed by the obſervation that the electric matter forces conducting bodies into its path. If a drop of water be laid on the prime conductor, in a poſitive ſtate, very long ſparks may be drawn from it, the drop will aſſume a pointed or conical ſhape, and wet bodies which are held near it: a proof that the water is thrown off. If the ſame experiment be made with melted ſealing-wax, the appearance is very peculiar and amuſing. The ſealing-wax muſt be dropped on or ſtuck to the ſide of the prime conductor, and afterwards melted with a candle; then if the conductor be electrified, either poſitively or negatively, the drop of wax becomes pointed, and ſhoots a number of fine threads into the air, to the diſtance of ſeveral feet. This thread is in the ſame ſtate of electricity as the conductor it iſſues from.

M It is remarkable that the drop of water which forms itſelf into a point by electrization does not give the ſpark when negatively electrified. This property is not, however, peculiar to water, but common to all very ſhort pointed conductors that riſe out of another ſurface nearly plane, and of ſome extent. A ſharp metallic point riſing about one thirtieth of an inch out of the ſurface of a ball of three inches diameter, gave ſparks five or ſix inches in length, when poſitive or emitting the electric matter; but the electricity paſſed without

out ſparks, and with ſcarcely any noiſe, when the point was negative or receiving. This may be an uſeful criterion for diſtinguiſhing the two ſtates.

Fig. 164, repreſents an inſtrument for diſtin- N guiſhing the electricities. A and B are two metallic balls, that may be placed at a greater or leſs diſtance from each other by means of the join at C. The two branches or legs C A, C B, are varniſhed glaſs. From one of the balls A, proceeds a ſhort point towards the other ball B. If the two balls be placed in the current or courſe of the electric matter, ſo that it may paſs through the air from the one to the other, its direction will be known. For if the electric matter paſs from A to B, there will be a certain diſtance of the balls dependant on the ſtrength of the electricity, within which denſe ſparks will paſs from the point: but if its courſe be in the contrary direction, no ſpark will be ſeen, unleſs the balls be almoſt in contact, and the point will be tipped with electric light.

CHAP. IV.

OF THE ELECTRICITY PRODUCED BY BRINGING A CONDUCTOR NEAR THE ELECTRIFIED PRIME CONDUCTOR: AND OF CHARGING AND DISCHARGING ELECTRIC PLATES.

o IF an inſulated conductor, free from points, be brought within a certain diſtance of the prime conductor or cylinder in an electric ſtate, it will alſo exhibit ſigns of electricity of the ſame kind; but if thoſe ſigns be removed, by taking the ſpark, and the conductor taken from the prime conductor, it will exhibit ſigns of the contrary electricity. This is a very remarkable appearance, but may be accounted for, if two ſuppoſitions be admitted, viz. firſt, that the electric matter is attracted by conducting bodies; and ſecondly, that the parts of the electric matter mutually repel each other, the forces of each power being in a certain inverted ratio of the diſtance.

p For the electric matter, in an inſulated and uniform conductor, will then be equally diffuſed through its whole maſs, and the attraction which that conductor will exert on any maſs of electric matter preſented from without, muſt be the exceſs of the attractive force of the body over the repulſive force of the electricity it contains. Whence a given conductor will attract the electric matter the

the moſt powerfully when the quantity it already poſſeſſes is the leaſt poſſible, and its attractive force will decreaſe as it becomes more ſaturated with electricity. Let two equal conductors, compoſed of like matter, be brought within a ſmall diſtance of each other, then, if the quantities of electricity they contain are equal, the attractions they mutually exert on thoſe quantities will be equal, and it will remain undiſturbed in each body. But if one conductor, A, contain more electricity than the other, B, the attractive power of B will be greateſt, and will draw the electric matter from A till an equilibrium is obtained. It Q follows alſo, that in a number of conducting bodies, communicating with each other, the electric matter will be every where of the ſame denſity, if the greateſt attractive force of the bodies be ſuppoſed equal; but if different bodies be ſuppoſed to attract the electric matter with different forces, as is moſt probable, the denſities muſt vary with the forces. This may be called the natural ſtate.

To apply this to the particular inſtance above R recited, ſuppoſe the end of an inſulated conductor to be brought near the prime conductor in a poſitive ſtate, the attractive power of the firſt-mentioned conductor is greater than that of the prime conductor, yet, not being ſufficient to draw ſparks, at the given diſtance, the only effect it can produce is, to make the electric matter accumulate, and become more denſe in that part of the prime conductor, near which it is preſented; by which accumulation

accumulation the reſt of the prime conductor becomes leſs electrified, as experience teſtifies. This accumulated body of electricity repels, and conſequently rarefies the electric matter naturally contained in that end of the conductor, which is preſented to the prime conductor; the reſt of the fluid becomes more denſe, and the other parts of the conductor which is preſented, exhibit ſigns of electricity; yet, as this conductor in the whole contains no more than its natural quantity, if the electric ſtate be taken off, by drawing the ſpark, and it be afterwards removed from the vicinity of the prime conductor, it becomes negative throughout, by reaſon of the loſs of the ſpark. If a conductor be preſented to the prime conductor in a negative ſtate, the effects are reverſed, the attraction being ſtrongeſt at the prime conductor, and the accumulation being in the conductor which is preſented, it exhibits a negative ſtate, which being deſtroyed, upon removal it becomes poſitive, by reaſon of the ſpark which was given to it when apparently negative.

Theſe effects are more conſiderable the leſs the diſtance is between the two conductors; and the intercedent electric body is peculiarly affected: the manner of which may be better underſtood, by obſerving the phenomena of non-electrics, ſeparated by electrics which are leſs liable to allow the paſſing of the ſpark than the air is.

Upon an inſulated horizontal plate of metal, lay a plate of glaſs, conſiderably larger, ſo that there

there may be a rim of three or four inches projecting beyond the metal on every side. Upon the glafs lay another plate of metal, of the fame fize as the former, fo as precifely to cover it. Electrify the upper plate, and the lower will exhibit figns of electricity. Continue the electrization, and the lower plate will emit fparks to an uninfulated body for a time, and afterwards ceafe. Separate the plates from the glafs without uninfulating them, and the glafs will appear to be poffeffed of the contrary electricities on the oppofite fides. That fide which communicated with the prime conductor, during the electrization, will have a like electricity, and the other the contrary. Take off the electricity of the plates of metal, and carefully replace the glafs on the lower, without deftroying the infulation, and alfo replace the upper plate with the fame precaution. Then, with one end of an infulated wire, not pointed, but knobbed at the ends, touch one of the plates, and bring the other end near the other plate: the confequence will be, that a ftrong and loud fpark will pafs between it and the wire, the electricity of the glafs will be difcharged, and the plates and the wire will exhibit few or no figns of electricity.

An electric body, whofe furfaces are thus poffeffed of the contrary electricities, is faid to be charged. The infulation of the lower metallic plate and of the difcharging wire is not neceffary, except for the purpofe of drawing inferences, re-

fpecting

ſpecting the manner of charging the electric plate. If the electricity of the prime conductor be ſtrong, and the glaſs thick, the diſcharge will often be made by a ſpark from the one metallic plate to the other, over the ſurface of the glaſs which projects on every ſide; but if the glaſs plate be thin, in which caſe, at an equal intenſity, it admits of a much greater charge, the diſcharge will be made through its ſubſtance. Glaſs, as thick as one eighth of an inch, may be penetrated by this means, one or more holes being made where the electric matter has paſſed, in which holes the glaſs is pulverized, and may be picked out with a pin.

w The greater the ſurface of the glaſs, the greater charge it will contain, the ſame intenſity being ſuppoſed. But a given machine will not ſuperinduce ſo ſtrong an electric ſtate on a large plate as a ſmall one: the reaſon of which ſeems to depend on the different intervals of time required in the charging, conjoined with the different magnitudes of the ſurfaces at which the electricity is communicated to the air. If there were no eſcape of the electric matter during the time of charging, the times would probably be as the ſurfaces of the plates, equal thickneſſes being always ſuppoſed; and if two plates were equally charged, the eſcape
x would perhaps be likewiſe as the ſurfaces. Theſe being premiſed, the whole eſcape would be as the time of charging, and the ſurfaces of each conjointly, that is, becauſe the times are as the ſurfaces, in the duplicate ratio of their ſurfaces directly.

rectly. Hence it appears that the eſcape in plates, that increaſe in ſize, approaches rapidly and continually nearer to the quantity of electricity ſupplied by the machine, and that the more powerful machine, by diminiſhing the time of charging, will charge higher in the inverſe proportion of the time. It muſt be confeſſed that the ſuppoſitions not being accurate, the proportions are only nearly true, yet this way of conſidering the ſubject may ſerve to indicate the cauſes, though not ſtrictly to meaſure the effect.

From the experiment (324), of ſeparating the Y
glaſs from the plates of metal, it is ſhewn, that the ſurplus of the electricity on one ſurface, is either accurately or very nearly equal to the deficiency on the other; for if it were otherwiſe, the plates and the diſcharging wire would become ſtrongly poſſeſſed of the predominating electricity.
It alſo follows, that if the theory of poſitive and Z
negative electricity be true, electric bodies muſt contain the electric matter, for the electric ſtates are evidently on the ſurfaces of the glaſs, independent of the metal. Now, though it may eaſily be underſtood that a poſitive ſtate may be ſuperinduced by an accumulation of electricity on one ſurface, yet it is abſurd to ſuppoſe that the electric matter can be emitted and exhauſted from the other ſide, if it did not exiſt there, previous to
ſuch emiſſion and exhauſtion. From this circum- A
ſtance it may be concluded, according to the ſame theory, that all bodies, as well electrics as nonelectrics,

electrics, attract the electric matter, but that electrics, being so constructed as not to admit it into their substance, as non-electrics do, must condense it upon their surfaces, and at all times hold a great quantity so condensed. And if the quantity of electricity be increased or diminished on one side, the electricity on the other surface must be rarefied or condensed, in consequence of the diminution or increase of the whole attractive force of the body. The effects will also be more considerable the less the distance is between the two surfaces (321, o).

A It is not possible to charge an electric plate by inducing an electric state on one of its surfaces, unless the other be at the same time sufficiently near to an uninsulated non-electric to assume the contrary state by emitting or receiving the electric matter.

B If a plate of glass be laid upon an uninsulated plate of metal, the upper surface may be rendered electric by friction, or by applying an electrified body successively to its parts. This electricity may be taken off by touching the upper surface with an uninsulated metallic plate of the same dimensions as that upon which the glass is placed, but will not be entirely taken off, because the communication between the two surfaces in this method is not perfect, and because the metal cannot by ordinary means be brought into actual contact with the glass. The small quantity which remains, produces an effect which has been

C mistaken for a perpetual electricity. For if a plate of

of metal, to which a glaſs handle is affixed, be laid upon the glaſs, this ſmall quantity of electricity will influence the metal, and, without actually communicating the electric matter, will cauſe it to exhibit a ſimilar ſtate (322). If this be taken off, by drawing the ſpark, and the metal then removed, by means of the glaſs handle, it will be found poſſeſſed of the contrary ſtate of electricity, and another ſpark may be obtained. The metallic plate may be then again applied to the ſurface of the glaſs, and the proceſs again repeated, and ſo on for a prodigious number of times, without any ſenſible difference in the event. For the electricity at the ſurface of the glaſs being almoſt in the natural ſtate, as to condenſation, does not diſappear for a very long time, and the very near approach of the metal enables it to produce the ſame effect as would be obtained at a greater diſtance from a ſtronger electricity (321, o). This is made obvious, by bringing the metallic plate near the ſurface of the glaſs before its firſt ſtrong electricity is taken off, for the ſame event is then perceived at the diſtance of four, five, or ſix inches, as in the former caſe is produced by contact.

The vapors of the atmoſphere are continually D
attaching themſelves to the ſurface of cold glaſs, and by that means deſtroy the electricity. Sulphur, wax, or reſin, being leſs ſubject to this, retain their electric ſtate much longer. A plate of glaſs or wood, coated over with any ſubſtance

of

of this nature, may be excited by friction, and will produce electricity in a metallic plate, in the manner above deſcribed for a very great length of time. Such a plate, together with its metal, has been named the electrophorus, fig. 165.

E If the diſcharge of an electrified plate be made by the parts of a living animal, a conſiderable pain will be felt chiefly at the extremities of the muſcles. For example, if the lower metallic plate be touched with one hand, and the other brought to the upper plate, at the inſtant of the emiſſion, a pain will be felt at the wriſts and elbows, which as inſtantly vaniſhes. If a larger glaſs plate be uſed, the pain will be felt in the breaſt; if yet larger, the ſenſation will be that of a univerſal blow. This ſenſation has obtained the name of the ſhock, and will deprive animals of life, if ſufficiently ſtrong. The ſhock from 30 ſquare inches of glaſs, well charged, will inſtantly kill mice, ſparrows, or other ſmall animals. Six ſquare feet of glaſs will deprive a man of ſenſation for a time, if the head be made a part of the circuit through which the electricity moves. No inconvenience has been found from the electric ſhock by men of ſtrong habits, but women of delicate conſtitutions
F have had convulſions from a violent ſhock. It may be obſerved, that the electric ſhock is a proof that the electric matter can paſs through the ſubſtance of non-electrics, and is not univerſally conducted along their ſurfaces alone, as ſome have ſuppoſed.

CHAP.

CHAP. V.

OF ELECTRIC JARS; THE VELOCITY OF THE SHOCK; LIGHT IN THE BOYLEAN VACUUM; THE CHARGING A PLATE OF AIR, WHENCE IS DEDUCED THE ACTION OF POINTED BODIES.

For the ſake of ſimplicity and preciſion, the G
effects of electricity, in charging glaſs, have been
deſcribed as they happen in flat pieces or plate.
Theſe, however, are ſeldom uſed. The object
of the philoſopher, in general, is to collect a large
quantity of electricity, by means of the ſurfaces
of electrics, and it is neither neceſſary nor convenient to uſe flat plates. He therefore accommodates himſelf with a ſufficient number of prepared jars. Theſe are made of various ſhapes and H
magnitudes, but the moſt uſeful are thin cylindrical glaſs veſſels, about four inches in diameter, and fourteen in height; coated within and without, with tin-foil, which is ſtuck on with gum-water, paſte, or wax, excepting two inches of the rim or edge, which is left bare, to prevent the communication between the coatings. About four inches from the bottom, within, is a large cork, that receives a thick wire, ending in ſeveral ramifications, which touch the inſide coating; the upper end of the wire terminating with a knob, conſiderably above the mouth of the jar. When it is required to be charged, it may be held in the

hand, or placed on an uninſulated table, and the
knob of the wire applied to the conductor; the
inſide coated ſurface becomes poſſeſſed of the elec-
tricity of the conductor, and the external ſurface
acquires the contrary electricity, by means of its
uninſulated coating. When a jar of this kind is
highly charged, it will diſcharge ſpontaneouſly over
the uncoated ſurface, and ſeldom through the
glaſs, whereas, when the uncoated ſurface is large,
they are more apt to break by that means, and
I become uſeleſs. Yet, there is no certainty that
a jar, which has diſcharged itſelf over its ſurface,
will not at another time break by a diſcharge through
the glaſs, as the contrary often happens.

K A jar of conſiderable thickneſs, with a neck
like a bottle, in which is cemented a thick tube
to receive the wire, will ſuſtain a very high
charge, and produce much greater effects than
one of the laſt deſcription. The charging wire
being inſerted looſely into the tube, will fall out
on inverting the jar, and the charge will remain
for ſeveral weeks without much loſs. A jar thus
charged, may be put into the pocket, and applied
to many purpoſes that the common jar cannot be
uſed for.

When a greater degree of electric force is re-
quired, larger jars muſt be uſed, in which the
form is of no conſequence, except as far as re-
lates to convenience. But it is leſs expenſive,
and nearly as effectual, to uſe a number of
ſmaller jars, having the ſame quantity of coated
ſurface

ſurface as the large jars. In this caſe, a com-
munication muſt be formed between all the out-
ſide coatings, which may be done by placing them
on a ſtand of metal; and alſo between all the inner
coatings, which is beſt done by means of wires.
Such a collection is called a battery, and may be
charged and diſcharged like a ſingle jar.

In diſcharging electrical jars, the electricity M
goes in the greateſt quantity through the beſt con-
ductors, and by the ſhorteſt courſe. Thus, if a
chain and a wire, communicating with the outer
coating, be preſented to the knob of a jar, the
greater part of the charge will paſs by the wire
and very little by the chain, which is a worſe con-
ductor, by reaſon of its diſcontinuation at every
link. When the diſcharge is made by the chain
only, ſparks are ſeen at every link, which is a
proof that they are not in contact; and as the chain
muſt be ſtretched by a conſiderable force before
the ſparks ceaſe to appear on the diſcharge, it fol- N
lows that there is a repulſive power in bodies,
by which they are prevented from coming into
contact, unleſs by force, as has been obſerved in
the former part of this treatiſe (I. 14, A; I. 48,
A, B).

By accurate experiments it appears, that the O
force of the electric ſhock is weakened, that is,
its effects are diminiſhed, by uſing a conductor of
great length in making the diſcharge. Yet, a
very conſiderable ſhock was given by the Abbé
Nolet, in the preſence of the French King, to one

hundred and eighty men; the firſt of whom formed a communication with the outer coating, the reſt joining hands in a circular line, and the laſt touched the knob of the inner coating. They were all ſhocked at the ſame inſtant. Dr. Watſon, and many other gentlemen of eminence in the philoſophical world, were at the pains of making experiments of the ſame kind, but much more ac-
P curate. They found, by means of wire inſulated on baked wood, that the electric ſhock was tranſmitted inſtantaneouſly through the length of 12276 feet.

Q When any animal or ſubſtance is to be ſubjected to the ſhock, it is uſually done by means of two chains, one of which connects one extremity of the animal or ſubſtance with the outer coating, and the other being faſtened to, or laid on, the other extremity, is applied to the knob of the inner coating to make the diſcharge. The animal or ſubſtance thus forming a part of the circuit,
R receives the whole ſhock. The ſtrong ſhock of a battery will melt wire of the ſeventieth of an inch in diameter, and wires of leſs diameters are fre-
S quently blown away, and diſperſed. Gunpowder may be fired by a charge of three ſquare feet: the method is, to put it into a quill, and thruſt a wire into each end, ſo as not to meet, and then make theſe wires a part of the circuit. A leſs charge will ſerve, if iron filings be mixed with the
T gunpowder. Spirit of wine, ether, or a mixture of common and inflammable air, may alſo be fired

by

by the ſame means, or even by the ſpark from the conductor.

If the ball of a thermometer be placed in a u ſtrong current of electricity, the mercury or ſpirit will riſe many degrees*.

A ſtrong ſhock gives polarity to ſmall needles. v

Electricity will paſs by means of non-electrics w that are ſo ſmall as to be deſtroyed by its paſſage, as has juſt been inſtanced in wires: the force of the exploſion in theſe inſtances is very conſiderable, and is termed the lateral force of electricity. The following is a proof of this, and may be exhibited with leſs than a ſquare foot of coated glaſs, if well charged. At the glaſs-houſe there is uſually x a great number of ſolid ſticks of glaſs, about a quarter of an inch diameter; if theſe be examined narrowly, ſeveral of them will be found to be tubular for a conſiderable length, but the diameter of the cavity ſeldom exceeds the 200th part of an inch. Select theſe, and break off the tubular part, which may be filled with quickſilver by ſucking; care being taken that no wet previouſly inſinuates itſelf, and then ſend the ſhock through this ſmall thread of quickſilver, which will inſtantly be diſploded, and will break or ſpilt the tube in a curious manner.

If a piece of the common glaſs tube be drawn y out very ſmall, by means of the blow-pipe, and

* From 67 to 99 degrees, in a ſmall mercurial thermometer. See Nairne's Deſcription of his Electrical Machine, London, 1783.

then filled with mercury, the ſhock will cauſe both the mercury and the tube to diſappear in the exploſion; nothing being ſeen but ſmoke or vapour.

Z An experiment ſimilar to theſe may be made with a glaſs-tube filled with water. Take a ſmall glaſs-tube, whoſe cavity is about a quarter of an inch in diameter, fill it with water, and ſtop the end with ſoft pomatum: through the pomatum inſert two wires, that they may almoſt touch each other, and make their ends a part of the circuit in the diſcharge of a ſtrong ſhock, from about two feet ſquare of coated glaſs; the conſequence will be, that the water will be diſperſed in every direction, and the tube blown to pieces, particularly in the middle, near the diſcontinuation of the wire: the ends with the wires and pomatum will ſometimes be found undiſturbed. This is a ſtriking inſtance of the velocity and force with which the electric matter is moved (1. 40.)

A This property, of being charged and diſcharged, is not peculiar to glaſs, but is common to all other electrics.

B If a thin bottle be exhauſted of air by means of the air-pump, it will receive a conſiderable charge by applying its bottom to the electrified prime conductor, during which time the electric matter will paſs through the vacuum between the hand and the inner ſurface of that part of the glaſs

B which is neareſt the prime conductor. This appearance, whoſe cauſe has already been in ſome degree

degree explained (318), is exceedingly beautiful in the dark, eſpecially if the bottle be of a conſiderable length. It exactly reſembles thoſe lights which appear in the northern ſky, and are called ſtreamers, or the aurora borealis. If one hand be applied to the part of the bottle which was applied to the conductor, while the other remains at the neck, the ſhock will be felt, at which inſtant the natural ſtate of the inner ſurface is reſtored by a flaſh, which is ſeen pervading the vacuum between the two hands.

The electric ſhock may be given from a plate c
of air, by means of two large plates of metal, or rather boards covered with tinfoil; one of which is to be ſuſpended to the prime conductor, and the other placed parallel to it on an uninſulated ſtand, at a convenient diſtance. Theſe boards may be regarded as the coatings of the plate of air contained between them, and if a communication be formed between them, by touching the uninſulated board with one hand, and applying the other hand to the conductor, the ſhock will be felt accordingly. It is almoſt unneceſſary to obſerve, that if the electricity be powerful, or the diſtance between the plates ſmall, the charge will paſs from the one to the other in a ſpark through the air.

If we compare this experiment with what has D
already been obſerved reſpecting the charging and diſcharging electric bodies, it will appear that moſt of the electric phenomena are the conſequences

of the air being charged. Thus, the prime conductor imparts its electricity to the ſurface of air immediately contiguous, and when the ſpark is drawn the diſcharge is made to the non-electrics, namely, the floor and wainſcot of the room, which are in contact with the oppoſite ſurface. The charge of electrics has already been obſerved to be greater (323, T) the nearer the ſurfaces are to each other; thus, glaſs beyond half an inch thickneſs
E can ſcarcely be charged by our machines: in like manner, the diſcharge, that is to ſay, the ſpark from the conductor, will be greater, when a large company ſtand about it than at other times, the body of air which is interpoſed between the conductor and the neareſt uninſulated non-electrics being then leſs in thickneſs than at other times.
F It follows alſo, that a large conductor will give a larger ſpark than a leſs; the diſcharge being from a ſurface proportionally greater. And ſince this diſcharge conſiſts chiefly of the electric matter, reſiding at, or near the ſurface of contact, and little, if at all, of that which may be within the
G ſubſtance of the conductor, it is of no conſequence whether the conductor be a ſolid non-electric or hollow, provided the ſurface be unaltered in form and magnitude. Hollow cylinders of copper, or tin, or wood, or paſteboard, covered with tinfoil, or ſtrongly gilt, are the conductors generally in uſe.

H It is a conſequence of the air being charged that broad non-electric ſurfaces draw large ſparks from the

the conductor; for the ſparks are the diſcharges of a large plate of interpoſed air. A leſs ſurface will draw a leſs ſpark, but becauſe the ſame machine charges leſs ſurfaces higher than greater, the ſpontaneous diſcharge through the body of the electric air will be made at a greater diſtance of the ſurfaces, that is to ſay, the ſparks will be longer. If the ſurface of the non-electric preſented be yet leſs, the ſparks, for the ſame reaſon, will be leſs, and emitted to a ſtill greater diſtance. And if the ſurface be indefinitely ſmall, or, in other words, if the non-electric be pointed, the ſpark may be ſo ſmall as to be inviſible, and the diſtance to which it can be emitted may be unlimited. The effect of pointed bodies ſeems to depend on circumſtances of this nature; but the reaſon of the different appearances of the light on points electrified, poſitively or negatively, ſtill remains a difficulty.

CHAP. VI.

AN ACCOUNT OF SEVERAL INSTRUMENTS, AND OF THE PRODUCING AN ELECTRIC STATE WITHOUT EVIDENT FRICTION.

K THE condenſer is an inſtrument of the ſame kind as the electrophorus, but differently uſed. For inſtead of the interpoſed electric being previouſly charged, it is of great importance here, that it ſhould be perfectly in the natural ſtate. In this ſituation if the upper conducting plate be connected with a larger body weakly electrified, while the lower plate is uninſulated, the upper will receive the electric ſtate, and on being ſeparated or lifted up, will exhibit it with a much higher degree of intenſity. So that very ſmall degrees of electricity may be rendered ſenſible by this admirable contrivance.

L To explain the cauſe of this, it muſt be recollected that the action of a neighbouring conductor diminiſhes the intenſity of the electric ſtate in another conductor, more eſpecially if the former be uninſulated. The electrified inſulated conductor will therefore admit of a more conſiderable degree of electrization before its intenſity can be rendered equal to what it was when ſolitary. Suppoſe this done, and the additional conductor then removed, and

and it is evident that the electrified conductor will, by the uniform diffuſion of the electricity, be left in a higher ſtate of electrization than it would have acquired by the ſame means without the aſſiſtance of the uninſulated conductor. The M two plates of the condenſer are in theſe circumſtances: the upper receives more electricity, becauſe of the vicinity of the lower, and ſhews a greater intenſity when removed out of that vicinity.

To accompliſh this purpoſe, in the moſt effec- N tual manner, it is neceſſary that the interpoſed electric be very thin (323, T) and that the ſurfaces be well adapted to each other. The electric may be a coat of varniſh laid on the lower or upper plate, or a thin ſilk faſtened to the ſurface of the upper.

If the electricity be ſtrong enough to charge O the electric, the acquiſition of the electric ſtate by the metal will be counteracted on the electrophorus principle, and the charge will tend greatly to diſturb and falſify the reſults of experiments made while it remains. A ſlight warming of the varniſh, either by the ſun or any other gentle heat, will however diſſipate it. But the beſt remedy for this, is to uſe ſuch an apparatus as will neither retain a charge nor ſuffer the metallic plate to obtain a higher electric ſtate than it can carry off on its ſeparation.

The ſagacious inventor has therefore ſubſtituted, P inſtead of the lower or fixed part of the apparatus, a piece

a piece of dry marble, or marble varniſhed with copal varniſh and kept in an oven for a ſhort time, or very dry wood. Here the very thin ſtratum of air between the metal plate and the ſubſtance it reſts on, ſeems to ſupply the place of the electric, and the imperfectly conducting power of the marble or the wood, prevents any charge from being accumulated. This laſt apparatus alſo performs its office better than the other.

Q To uſe this inſtrument the metallic plate is to be laid on the marble or varniſhed metal, and a connection formed between the upper plate and the body whoſe electricity is to be examined. This connection may remain eight or ten minutes, or longer, if the electricity be very weak, and then be removed. The metal plate being lifted up, will exhibit ſigns of electricity if the connected body were in an electric ſtate*.

R Various inſtruments have been contrived to diſcover the preſence of electricity, together with its intenſity and kind. Theſe have been adapted to obſerve either the attraction, or repulſion, or the length and figure of the ſpark.

* The electrophorus and condenſer were invented by Mr. Alexander Volta, Profeſſor of Experimental Philoſophy at Como, &c. This laſt inſtrument is honourable to its inventor, not only on account of the extenſively uſeful purpoſes to which it has been and may be applied; but likewiſe becauſe it was diſcovered, not caſually, like moſt other electrical apparatus, but in conſequence of ſcientific deduction and reaſoning. See Phil. Tranſ. Vol. 72, Part 1, or Cavallo's Electricity.

Small

Small degrees of electricity are very well ſhewn s
by the divergence of two fine hempen-threads, ſuſpended together from the conductor. If little T
balls of pith or cork be faſtened to the ends of the threads, they will ſerve to denote ſtill greater intenſities, as they will not ſo ſoon arrive at their utmoſt divergence by the mutual repulſion. Fig. U
167, is a very uſeful electrometer upon this principle. It conſiſts of an upright ſtick of box-wood, A B, on one ſide of which is affixed a graduated ſemi-circle; D is a ball of pith or cork, and is ſtuck upon the end of a ſmall rod or radius of wood, which, by means of a ſmall axis at C, is moveable in a plane parallel to that of the ſemicircle. This electrometer is fixed upright on the prime conductor; the radius will therefore hang perpendicularly down when it is not electrified; and according to the intenſity of the electric ſtate given to the conductor, the repulſion muſt cauſe the ball to aſcend. The aſcent will be marked by the graduations.

This electrometer, though very uſeful, has the V
imperfection of being leſs ſenſible of the changes of electricity when the intenſity is conſiderable, than when the repulſion at the beginning of the ſcale acts at right angles to the radius. It has alſo another inconvenience common to all electrometers, namely, the want of a ſtandard of original adjuſtment, by means of which all inſtruments of the kind may indicate the ſame intenſity in ſimilar circumſtances.

W Fig. 168, reprefents an electrometer for meafuring the length of the fpark. A reprefents a fection of the prime conductor; the wooden ftem B being inferted therein. The bent part D is varnifhed glafs. Through a wooden collar C paffes a wire that carries a ball of metal E, which may be fet at different diftances as required. A chain may be hung on the outer part I. This electrometer is chiefly ufeful for fhocks, greater or lefs as may be required. For this purpofe the knob of the jar muft be in contact with the prime conductor, and a chain from F muft touch the external coating. When the charge is fufficiently high, the explofion will be made through the interval between A and E.

X Fig. 169, is a very fenfible electrometer, well adapted for the obfervation of the prefence and quality of either natural or artificial electricity. A B C is the brafs cafe containing the inftrument. When the part A B is unfcrewed and the electrometer taken out, it appears as reprefented in A B D C. A glafs tube C D N M is cemented into the piece A B. The upper part of the tube is fhaped tapering to a fmall extremity, which is entirely covered with fealing-wax. Into this tapering part a fmall tube of glafs is cemented; the lower extremity being alfo covered with fealing-wax, projects a fmall way within the tube C D M N. Into this fmaller tube a wire is cemented, which, with its under extremity, touches a flat piece of ivory H, faftened to the tube by means of a cork. The upper extremity of the

wire

wire projects about a quarter of an inch above the tube, and ſcrews into the braſs cap E F, which cap is open at the bottom, and ſerves to defend the waxed part of the inſtrument from the rain, &c. From H are hung two fine ſilver wires, having very ſmall corks at their lower ends, which by their repulſion ſhew the electricity. I M and I N are two ſlips of tin-foil ſtuck to the inſide of the glaſs, and communicating with the braſs bottom A B. They ſerve to convey that electricity, which, when the corks touch the glaſs, is communicated to it and might diſturb their free motion.

To uſe this inſtrument for artificial electricity, Y
bring a body in an electric ſtate (a ſtick of ſealing-wax, previouſly rubbed, is as convenient as any) near the braſs cap; the corks (321, o) will diverge with the ſame electricity till one of them touches the tinfoil I M or I N, when they will immediately collapſe. Remove the electrified body, and the corks will again diverge with the contrary electricity. In this ſituation, ſuppoſing ſealing-wax to have been uſed, a body poſſeſſed of the poſitive electricity being brought near the cap will cauſe the corks to diverge ſtill more; but if negative, it will cauſe them to approach nearer to each other.

When this electrometer is to be uſed to try the Z
electricity of the fogs, air, clouds, &c. the obſerver is to do nothing more than to unſcrew it from its caſe and hold it by the bottom A B, to preſent it to the air in an open place a little above his head, ſo

ſo that he may conveniently ſee the corks P. A very ſmall degree of electricity will cauſe them to diverge, and its quality may be aſcertained by bringing an excited ſtick of ſealing-wax, or other electric, towards the cap E F.

But the electrometer of Bennet, is by far the moſt delicate of any of the inſtruments which have yet been applied for diſtinguiſhing ſimple electricities.

It conſiſts of two ſlips of leaf gold, A, fig. 166, ſuſpended in a glaſs B. The foot C may be made of wood or metal; the cap D of metal. The cap is made flat on the top, that plates, books, evaporating water, or other things to be electrified, may be conveniently placed upon it. The cap is about an inch wider in diameter than the glaſs, and its rim about three quarters of an inch broad, which hangs parallel to the glaſs, to turn off the rain and keep it ſufficiently inſulated. Within this is another circular rim, about half as broad as the other, which is lined with ſilk or velvet, and fits cloſe upon the outſide of the glaſs; thus the cap fits well, and may be eaſily taken off to repair any accident happening to the leaf gold. Within this rim is a tin tube, hanging from the center of the cap, ſomewhat longer than the depth of the inner rim. In the tube a ſmall peg is placed, and may be occaſionally taken out. To the peg, which is made round at one end and flat at the other, the ſlips of leaf gold are faſtened with paſte, gum-water, or varniſh. Theſe ſlips, ſuſpended by the peg, and that in the tube faſt to the cen-

ter of the cap, hang in the middle of the glaſs, about three inches long, and a quarter of an inch broad. In one ſide of the cap there is a ſmall hole to place wires in. It is evident, that without the glaſs the leaf gold would be ſo agitated by the leaſt motion of the air, that it would be uſeleſs; and if the electricity ſhould be communicated to the ſurface of the glaſs, it would interfere with the repulſion of the leaf gold, therefore two long pieces H H of tin foil are faſtened with varniſh on oppoſite ſides of the internal ſurface of the glaſs, where the leaf gold may be expected to ſtrike, and in connection with the foot. The upper end of the glaſs is covered and lined with ſealing wax as low as the outermoſt rim, to make its inſulation more perfect *.

The ſenſibility of this inſtrument is ſo great as even to aſtoniſh the moſt experienced electricians who have not before been witneſs to its effects. The bruſh of a feather, the projection of chalk, hair-powder, or duſt, againſt its cap evince ſtrong ſigns of electricity. The electricity of vapor is elegantly ſhewn by pouring a tea-ſpoonful of water on an agitated coal placed in a metallic cup upon the cap of this electrometer: and a very great and pleaſing variety of other experiments may be made with this excellent inſtrument.

The ingenious electrician who is not provided with the inſtruments here deſcribed, may ſupply

* Phil. Tranſ. vol. 74, p. 27.

their place by contrivances which a knowledge of the general facts will easily indicate. Strong electricities may be distinguished by the light at the extremities of pointed bodies, and for less intensities a downy feather may be suspended by a fine thread of silk. This being electrified, by bringing it in contact with the cylinder or conductor of a machine, will preserve its electric state for a considerable time; during which it will be repelled by bodies in the same state, and attracted by all others.

B We shall finish this general account of artificial electricity with pointing out some of the other means of producing it, which do not seem referable to the usual method of excitation.

C The escape of vapor or elastic fluid from bodies in a state of combustion, from water thrown on hot coals, or from chemical menstrua in a state of effervescence, leaves the residue negatively electrified. These important facts seem to point at a general law of electricity, that may tend in future to explain the phenomena in which heat is latent (117, T), and to which it bears a striking analogy*.

D It appears to be a fair deduction from these facts, that as bodies take up electricity when they assume an elastic form, so they must deposit it when they are again condensed. The experiments relative to this object require to be varied and extended.

* The discovery of Sig. Volta. See Phil. Transf. vol. 72.

Sulphur

Sulphur melted in an earthen veſſel, and placed E
to cool upon uninſulated conductors, is ſtrongly electric when taken out, but is not ſo when it has ſtood to cool upon electric ſubſtances.

Sulphur melted in a glaſs veſſel acquires a ſtrong F
electricity in the circumſtances above mentioned, whether the veſſel be placed on electrics or not; but ſtronger in the former caſe. This electricity is yet ſtronger, if the glaſs be coated with metal. In theſe caſes the glaſs is always poſitive, and the ſulphur negative. It is particularly remarkable, that the ſulphur acquires no electricity till it begins to cool and contract, and is the ſtrongeſt at the time of the greateſt contraction: whereas the electricity of the glaſs is at that time weakeſt, and is the ſtrongeſt of all when the ſulphur is ſhaken out before it begins to contract, or has acquired any negative electricity*.

It has been obſerved, that ſilk or worſted ſtock- G
ings become electrical after being worn ſome hours, more particularly the ſilk, as does alſo a beaver ſhirt worn between two others. If a white and a black ſilk ſtocking be worn on the ſame leg, they obtain contrary electricities. When drawn off together they ſhew very little ſigns of electricity, but, upon ſeparating them, each indicates an electrical ſtate ſo ſtrongly, that the repulſion inflates them, ſo as to exhibit the intire ſhape of the leg. If the two ſtockings be allowed to come

* Theſe facts are denied by Volta, in Phil. Tranſ. vol. 72.

together, they ſtrongly attract each other, the inflation ſubſides, and they ſtick very cloſely together; in which ſituation they retain their electric ſtate, notwithſtanding the approach of the ſharpeſt metallic point. A ſecond ſeparation again exhibits their reſpective electricities as before; and this may be done ſeveral times without much diminiſhing their electricities. The electricity of the black ſtocking is negative, and of the white poſitive. It is exerted by the friction of drawing the ſtockings from the leg.

H The tourmalin is a hard gem, either pellucid or opake, of a red colour, and is brought from the iſland of Ceylon, by the Dutch. It poſſeſſes the property of aſſuming an electric ſtate if heated; one ſide of it becoming poſitive, and the other negative. If this electric ſtate be taken off by contact, the ſtone will become electric as it cools; but with this difference, that the ſide which, during the heating, was poſitive, will now be negative, and the other ſide poſitive, which before was negative. But if the electric ſtate be not taken off, the ſame kind of electricity will be found on the ſame ſide during the whole time of heating and cooling. Either ſide of the tourmalin will become poſitive by friction, and both may be made ſo at the ſame time.

I Theſe are the chief properties of this very remarkable ſtone, which are alſo common to the Brazil topaz, and ſome other gems. There are ſeveral important particulars relative to this and

every other branch of electrical knowledge, which cannot be enumerated and defcribed, in an introductory book, on account of the great length of detail they would require. For thefe, the ftudent muft have recourfe to treatifes written exprefsly on this fubject. There are alfo a number of fanciful and pleafing variations of the common experiments. Bells are rung by an uninfulated clapper, which is alternately attracted and repelled between two bells in oppofite ftates of electricity; figures cut in paper are made to dance by the attraction and repulfion between two metallic plates; light mills of pafteboard are driven round by the current of air from electrified points, &c. &c. particular accounts of all which may be had in pamphlets, which are frequently fold by the makers of the electrical apparatus *.

* For a fuller account of electrical difcoveries and apparatus, confult Prieftley's Hiftory of Electricity; Adams's Effay on Electricity, or Cavallo's Complete Treatife.

CHAP. VII.

OF NATURAL ELECTRICITY; AND OF THE IDENTITY OF LIGHTNING AND THE ELLCTRIC MATTER.

K THAT electricity is no trivial or confined ſubject, muſt appear from what has already been ſaid, ſince there is no body in nature that is not acted upon by it, either as a conductor or non-conductor. The importance of the electric matter in the ſyſtem of the world is more particularly confirmed by obſervations on thoſe phenomena which take place without the concurrent operation of man. Of theſe it will be proper to give ſome account.

L Several fiſhes poſſeſs the property of giving the electric ſhock. The torpedo, or numbing fiſh, and one or more ſpecies of eels, from Surinam, if touched by the hand, a metal rod, or any other conductor, give a conſiderable ſhock to the arm, but may be ſafely touched by means of a ſtick of ſealing-wax. The ſhock depends on the will of the fiſh, and is tranſmitted to a great diſtance, ſo that if perſons in a ſhip happen to dip their fingers or feet in the ſea, when the fiſh is ſwimming at the diſtance of fifteen feet, they are affected by it. Mr. Walſh exhibited the actual ſpark of exploſion by the Gymnoblus electricities from

from Surinam. For this purpoſe part of the circuit was formed of a ſlip of tinfoil paſted upon glaſs, and divided by one ſtroke of a ſharp knife. At this break the ſpark was ſeen very luminous and bright.

Many diſorders of the human frame have been M cured or relieved by electricity. In all caſes, except thoſe called nervous, the electric wind from a wooden or metallic point, the ſpark or gentle ſhocks may be ſafely adminiſtered without fear of doing harm, if no good effect ſhould be produced. This remedy ſeems peculiarly applicable to local diſorders, ſuch as ſwellings, contractions, rheumatic and other pains, palſies, &c. in which its effects are very often wonderfully ſudden and beneficial. The ſpark or ſmall ſhocks through the pelvis, regulated according to the feelings of the patient, are ſaid to be an infallible cure for the ſuppreſſion of the catamenia; and it is certain that in many deplorable caſes it has effected a cure. It is generally admitted as a rule in the application of electricity, that it ought never to be ſo ſtrong as to be diſagreeable to the patient in any conſiderable degree.

But the moſt remarkable appearances of elec- N tricity, which are viewed with ſurpriſe and admiration by all ranks of people, are thoſe which may be termed atmoſpherical, as for the moſt part exiſting in, or depending on, the ſtate of the atmoſphere. Lightning is proved to be an electric phenomenon, and there is little doubt but the au-

rora-borealis, whirlwinds, water-ſpouts, and earthquakes, depend on the ſame principle.

o The reſemblance between the electric ſpark and lightning, is ſo obvious, that we find it among the earlieſt obſervations on the ſubject; but the proof of the important theorem of their identity was reſerved for Dr. Franklin, who is ſo juſtly celebrated for his many diſcoveries in this branch of natural philoſophy. He firſt obſerved the power of uninſulated points, in drawing off the electricity from bodies at great diſtances, and thence inferred that a pointed metallic bar, if inſulated at a conſiderable height in the air, would become electrical by communication from the clouds during a thunder-ſtorm. He communicated this thought to the public; and ſeveral machines, conſiſting of inſulated iron bars, erected perpendicular to the horizon, and pointed at top, were ſet

P up in different parts of France and England. The firſt apparatus that was favored with a viſit from this ethereal matter, was that of Monſ. Dalibard, at Marly la Ville, about ſix leagues from Paris. It conſiſted of a bar of the length of forty feet, and was electrified on the tenth of May, 1752, for the ſpace of half an hour, during which time the longeſt ſparks it emitted meaſured about two inches.

Q Dr. Franklin, after having publiſhed the method of verifying his hypotheſis concerning the ſameneſs of electricity with the matter of lightning, was waiting for the erection of a ſpire in Philadelphia

Philadelphia to carry his views into execution; not imagining that a pointed rod of a moderate height could anſwer the purpoſe; when it occurred to him, that by means of a common kite he could have a readier and better acceſs to the regions of thunder, than by any ſpire whatever. Preparing therefore a large ſilk handkerchief, and two croſs ſticks of a proper length, on which to extend it; he took the opportunity of the firſt approaching thunder-ſtorm, to walk into a field in which there was a ſhed convenient for his purpoſe. But, dreading the ridicule which too commonly attends unſucceſsful attempts in ſcience, he communicated his intended experiment to nobody but his ſon, who aſſiſted him in raiſing the kite.

The kite being raiſed, the end of the ſtring being tied to a ſilk ſtring, which he held in his hand, and a ſmall key being faſtened at the place of junction, a conſiderable time elapſed before there was any appearance of its being electrified. One very promiſing cloud had paſſed over it without any effect; when, at length, juſt as he was beginning to deſpair of his contrivance, he obſerved ſome looſe threads of the hempen ſtring to ſtand erect, and to avoid one another juſt as if they had been ſuſpended on a common conductor. Struck with this promiſing appearance, he immediately preſented his knuckle to the key, and, let the reader judge of the exquiſite pleaſure he felt at the moment, the diſcovery was complete. He perceived a very evident electric ſpark. Others ſucceeded,

succeeded, even before the string was wet, so as to put the matter past all dispute; and when the rain had wetted the string, he collected the electricity very copiously. This happened in June 1752, a month after the electricians in France had verified the same theory, but before he had heard of any thing they had done.

s The grand practical use which the Doctor made of this discovery, was to secure buildings from being damaged by lightning, a thing of vast consequence in all parts of the world, but more especially in several parts of North America, where thunder-storms are more frequent, and their effects, in that dry air, more dreadful, than they are ever known to be with us.

T This great end is accomplished by so easy a method, and by so cheap and seemingly trifling apparatus, as fixing a pointed metalline rod higher than any part of the building, and communicating with the ground, or rather the nearest water. This wire the lightning is sure to seize upon, preferably to any other part of the building, unless it be very large and extended, in which case wires may be erected at each extremity; by which means this dangerous power is safely conducted to the earth, and dissipated without doing any harm to the building.

U Conducting rods are now become very common, both for the purpose of securing buildings, and of making observations on the state of the atmosphere. The best of those which are intended for

for the latter purpose, is the following. On the top of any building, which will be the more convenient if it ſtand upon an eminence, erect a pole as tall as a man can manage without difficulty, having on the top of it a ſolid piece of glaſs or baked-wood, a foot in length. Let this be covered with a tin or copper veſſel in the form of a funnel, to prevent its ever being wetted. Above this let there riſe a long ſlender rod, terminating in a pointed wire, and having a ſmall wire twiſted round its whole length, to conduct the electricity the better to the funnel. From the funnel, let a wire deſcend along the building, about a foot diſtance from it, and be conducted through an open ſaſh into any room which ſhall be moſt convenient for managing the experiments. In this room let a proper conductor be inſulated and connected with the wire coming in at the window. This wire and conductor, being completely inſulated, will be electrified whenever there is a conſiderable quantity of electricity in the air; and notice will be given when it is properly charged, either by the mutual repulſion of two ſmall balls of cork hung to it by threads, or by the ringing of two ſmall bells, the one ſuſpended from, and communicating with the conductor, and the other uninſulated: theſe bells will be in oppoſite ſtates of electricity when the conductor is electrified, and if a clapper or ſmall metallic ball be hung by a ſilk thread between them, it will be alternately attracted and repelled by each, and conſequently

quently indicate the electricity of the conductor
w by ringing. The condenser (339, K) is of excellent
use to ascertain the presence and quality of atmospherical electricity when the conductor is too slightly electrified to attract a thread, or to exhibit any of the usual appearances.

x To make these experiments in perfect safety, the electrified wire should be brought within a few inches of a conducting rod, which serves to guard the house, that the redundant electricity may pass off that way, without striking any person who may happen to stand near it. The conductor to guard the house should consist of a rod, without breaks or discontinuities, between one fourth and one half of an inch thick, if it be of iron, but smaller if it be of brass or copper, terminating upwards in a sharp point about four or five feet above the highest part of the building: it is convenient that this point be of gold, or gilt, to preserve it from rusting. The lower end of the rod should, if possible, be continued to some well or running water, or otherwise it should be sunk several feet into the ground, at the distance of some yards from the building. It is of no consequence how many bendings are made in the rod, but it is much better to fasten it to the outside than the inside of the building; for these conductors are known to emit sparks during thunder-storms, notwithstanding their insertion in the earth, from which fatal consequences may be apprehended when the electric force is very great.

It

It is clear, from many inſtances, that the lights Y
which are ſeen at the maſt-heads of ſhips, and on the vanes of ſome churches during thunder, owe their origin to the electric matter paſſing by means of uninſulated points.

The polarity of the compaſs-needles has been Z
known, in ſeveral inſtances, to have been deſtroyed or reverſed by lightning. An effect which, as has been obſerved, may be produced by the electric ſhock from glaſs (334, V).

If the electrician be deſirous of making experi- A
ments upon the electricity of the atmoſphere to greater exactneſs, he muſt raiſe a kite, by means of a ſtring in which a ſmall wire is twiſted. The lower extremity of this line muſt be ſilk, and the wire muſt terminate in ſome metallic conductor of ſuch a form as ſhall be thought moſt convenient. But it is dangerous to raiſe it upon the approach of a thunder-ſtorm; and upon this occaſion the common apparatus for drawing electricity from the clouds will probably anſwer every intended purpoſe.

CHAP. VIII.

OF LIGHTNING, AND OTHER METEORS.

B To know that lightning and the electric matter
are the ſame, is a great ſtep in natural philoſophy,
but we muſt ſtill remain ignorant of the cauſes of
many of the appearances which accompany light-
ning, ſo long as our acquaintance with the pro-
perties of electricity is ſo very imperfect. We
C know that the clouds are almoſt always electrified,
ſometimes poſitively, and ſometimes negatively;
but whence, or by what means, they acquire that
D ſtate; whether by the heating or cooling of the air,
upon the Tourmalin principle, whatever that may
E be, or whether the clouds be only the conductors
by which the electric matter is conveyed through
the air, from places in the earth where it is re-
dundant, to other places where there is a de-
ficiency, cannot eaſily be determined. The firſt
is the conjecture of the well-known Mr. Canton,
and the latter is the chief propoſition in the theory
of that great philoſopher Sig. Beccaria of Turin.
It is probable that both circumſtances may con-
duce to the effect; the heating or cooling of the
air may produce, or rather collect, that electri-
city, which is ſo great an agent in atmoſpherical
events, and its diſcharge may be effected in the
manner

manner in which Signor Beccaria has, with great probability, ſuppoſed it to be accompliſhed.

The diſcovery of Sig. Volta, of the electri- F
city of vapors, or elaſtic matter raiſed into the atmoſphere by fire or otherwiſe, is a moſt capital advance towards the perfect knowledge of the cauſe of the electric ſtate of clouds, miſts, and the like. For vapors, carrying off a larger portion of electricity than when in the fluid ſtate, muſt conſtantly give out a part of the ſame (346, D) when they arrive in the ſuperior and colder regions of the air, where they become more condenſed, and form clouds. Clouds and rain will therefore naturally have the poſitive electricity, though a cloud, when once formed, may, by its influence on neighbouring clouds, cauſe them to become negative (321, O), by imparting not only their natural ſurplus, but even more to the earth.

A thunder-ſtorm uſually happens in calm wea- G
ther. A dark cloud is obſerved to attract others to it, by which it continually increaſes in magnitude and apparent denſity. When the cloud is thus grown to a great ſize, its lower ſurface ſwells in particular parts towards the earth, ſometimes by light flimſy clouds, and ſometimes by an inferior protuberance. During the time that the cloud is thus forming, flaſhes of lightning are ſeen to dart from one part of it to the other, and often to illuminate the whole maſs; and ſmall clouds are

obſerved

obſerved moving rapidly, and in very uncertain directions beneath it. When the cloud has acquired a ſufficient extent, the lightning ſtrikes the earth in two oppoſite places; the path of the lightning lying through the whole body of the cloud and its branches.

That thunder-clouds frequently do nothing more than conduct the electric matter from one place to another, is not only probable, on account of its ſtriking in two places, but likewiſe from the conſideration, that the emiſſion of the flaſh would deſtroy the electric ſtate of the clouds, if it were not immediately recruited from ſome other part. But the electric ſtate is not deſtroyed after a flaſh, if we may judge either from the electric apparatus, or from the cloud itſelf; for the firſt appears to be not leſs electrified, and the latter is the next moment ready to make as great a diſcharge as before. Beſides, if the two flaſhes of lightning, which ſtrike at different places, nearly at the ſame time, were ſimple, ſimilar, and independent diſcharges of the cloud, why ſhould they reſemble each other? and yet they do very much, as appears by obſerving a thunder-ſtorm at a diſtance. Then it is ſeen, that if one part of the cloud give a ſingle flaſh, the other extremity will give, or rather receive, a ſingle flaſh a ſhort time or the inſtant after; but if it give two, three, or four quick ſucceſſive flaſhes, the other extremity will receive a like number a little, but very perceptible a time after. The angular diſtance between

tween the places of theſe correſpondent flaſhes is frequently four or five points of the compaſs.

It is remarkable, that moſt detached clouds, whoſe angular heights are but ſmall, and which conſequently may be viewed in profile, are variouſly arched at their upper ſurface, while their under ſurface is horizontal. This appearance is particularly obſervable in thunder-clouds, and alſo takes place in the ſmoke of reſin, or ſteam of water, electrified by the common machine. I

Whatever may be the cauſe that diſturbs the equilibrium of the electric matter in the atmoſphere, it may eaſily be conceived, that when ſuch diſturbance happens in the upper, and highly rarefied regions of the air, the equilibrium will be reſtored by dartings and electric coruſcations through the vacuum, ſimilar to thoſe exhibited in the vacuum of the air-pump. This conſideration accounts for the aurora borealis, which has commonly a motion of darting or undulating between two oppoſite parts of the heavens. K

In clear and calm weather, when the electricity is not very ſtrong, it may paſs through the air without bringing any great quantity of vapours into its courſe, and, according to the conductors it meets in the air, it will ſometimes be rendered viſible for ſmall parts of its paſſage, and occaſion thoſe appearances which we call ſhooting-ſtars. It is obſervable, that ſhooting-ſtars, ſeen at any time, in general all direct their courſe the ſame way.

M The balls of * fire, as well as the ſhooting-ſtars, occaſionally ſeen in the air, ſeem to be maſſes of electricity, at ſo great a diſtance that their angular velocity is not ſufficient to prevent the eye from diſcerning their ſhape. It is probable that every electric ſpark or flaſh of lightning conſiſts of one or more balls of fire, though their extreme velocity preſents them to the eye under the form of a line or lines (I. 259, O).

N The ignis fatuus, or Will-with-the-wiſp, is a luminous meteor that ſeldom appears more than ſix feet above the ground. It is found chiefly about bogs, and is always in motion, varying both its figure and ſituation in a very uncertain manner. In the plains in the territory of Bologna, they are frequently very large, and give a light equal to a torch; and there are ſome places where one may be almoſt ſure of ſeeing them every dark night. It has been conjectured that theſe meteors conſiſt of inflammable air, which has been kindled by electricity.

O It was obſerved of water-ſpouts, that the convergence of winds and their conſequent whirling motion, was a principal cauſe in producing that effect (63, L); but there are appearances which can hardly be ſolved by ſuppoſing that to be the only cauſe. They often vaniſh, and preſently appear again in the ſame place: whitiſh or yellowiſh

* Dr. Blagden has given a valuable ſtatement of facts and deductions reſpecting meteors of this kind in the Phil. Tranſ. vol. 74.

flames

flames have sometimes been seen moving with prodigious swiftness about them, and whirlwinds are observed to electrify the apparatus very strongly. The time of their appearance is generally those months which are peculiarly subject to thunder-storms, and they are commonly preceded, accompanied, or followed by lightning, the previous state of the air being alike in both cases. And the long established custom, which the sailors have, of presenting sharp swords to disperse them, is no inconsiderable circumstance in favour of the supposition of their being electrical phenomena. Perhaps the ascending motion of the air, by which the whirling is produced, may be the current known to issue from electrified points, as the form of the protuberance in the sea is somewhat pointed; and the electrified drop of water, heretofore mentioned, may afford considerable light in explaining this appearance.

It is extremely probable that earthquakes owe P
their original to the discharge between a cloud and the earth, in a highly electric state, or even between two clouds. They happen most frequently in dry and hot countries, which are most subject to lightning and other electrical phenomena; and are even foretold by the electric coruscations and other appearances in the air, for some days preceding the event. Earthquakes are attended by no fire, vapor, or smell, which however could hardly fail to appear, if the common opinion, of their being occasioned by a subterra-

neous exploſion, were true. The effect of an exploſion of this nature would be a gradual lifting of the earth, after which it would fall again, and, no doubt, deſtroy or change the courſe of ſprings, and conſiderably alter the face of the country: the contrary to all which is true; for, as far as obſervation can determine, the ſhock of an earthquake is inſtantaneous to the greateſt diſtances, and ſeldom does more miſchief than overthrowing buildings. Earthquakes are uſually accompanied by rain, and ſometimes by the moſt dreadful thunder-ſtorms. All theſe, and many more circumſtances, but eſpecially the almoſt inſtantaneous motion of the ſhock, induce us to look for their cauſe in electricity, the only power in nature that acknowledges no ſenſible tranſition of time in its operations.

Q Dr. Prieſtley, in his Hiſtory of Electricity, has given an abridgment of Dr. Stukely's obſervations and inferences on this ſubject, and has himſelf ſhewn, by experiment, that the electric ſhock cauſes a vibration ſimilar to that of an earthquake, when it paſſes at or near the ſurfaces of bodies.

R It may be here obſerved, that the knowledge we have of the properties of electricity has been acquired, for the greater part, within the laſt half century; and that if diſcoveries proceed as rapidly as they have began, it may be hoped, that a ſimilar period will afford a more perfect

acquaintance

acquaintance with the influence of electricity not only on atmospherical events, but likewise on magnetism, vegetation, muscular motion, and other appearances, in which, it is more than probable, this great and active power has a share.

THE END.

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